Technology Final Report
and
Joint Test Report

Tri-Service Dem/Val of the Pulsed Optical Energy Decoating (FLASHJET®) Process for Military Applications

U.S. Army Environmental Center

15 March 2002

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Technology Final Report

Tri-Service Dem/Val of the Pulsed Optical Energy Decoating (FLASHJET®) Process for Military Applications

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1. Introduction

1.1 Background Information

A major waste stream associated with Department of Defense (DoD) industrial maintenance facilities is toxic chemical and media blast materials associated with coating removal operations. From the 1994 Toxic Release Inventory (TRI) data for all DoD operations, coating removal operations accounted for approximately 20% of all waste (2.5 million pounds annually from a total of 11.3 million pounds total DoD waste). Chemical coating removal refers to the use of coating removers that often contain methylene chloride, phenols, and toluene, which are classified as hazardous air pollutants (HAPs). To replace chemical coating removal processes, many facilities switched to the more environmentally preferred method of media blasting. However, media blasting increases the tonnage of coating removal hazardous waste leaving the facility. These conventional coating removal operations have additional safety and health concerns for workers. Due to these undesirable attributes, military maintenance operations are compelled to re-evaluate current coating removal methods and search for alternatives. DoD facilities are also faced with Executive Order 13148 (formerly Executive Order 12856) where installations must decrease all waste disposal volumes by 50%. Additionally, DoD facilities are faced with complying with National Emission Standard for Hazardous Air Pollutant (NESHAP) regulations such as the Aerospace NESHAP. In 2004 the Miscellaneous Metal Parts and Products NESHAP regulation which will be final and a section of this regulation will deal with the controlling of HAPs during coating removal activities which will greatly impact coating removal operations involving ground and fighting vehicles.

A solution to the problems of using chemical coating removal processes and media blasting as stand alone coating removal methods has been developed. This process utilizes a pulsed optical energy system, specifically a xenon-flashlamp/carbon dioxide process known as the Flash Tech, Inc. FLASHJET® Coatings Removal Process. The process was sold from The Boeing Company to Flash Tech, Inc. in December 2001. The process is safe for use on steel, aluminum, fiberglass, titanium, and various composite substrates. The process can remove as little as 0.001” (25µm) of coating, which allows for the selective removal of topcoats without damaging underlying primers. The process is an alternative to other coating removal methods that is cost effective and environmentally preferable.

1.2 Official DoD Requirements Statement

Several efforts are underway within the DoD to find chemical coating removal and media blasting alternatives. In the U.S. Army Environmental Requirements and Needs Report, some requirements for finding alternatives to chemical coating removal processes and media blasting include: Contaminated Blast Media (2.3.n); Hazardous Air Pollutant Emission Control (2.1.g); and Alternate Paint Stripping Chemicals of Military Interest (3.2.h). The U.S. Navy requirements relating to coating removal activities include: Control/Reduce Emissions from Coating, Stripping, and Cleaning Operations (2.I.1.g); Control of VOC and HAP Emissions (2.I.1.q); and Non-hazardous Coating System Removal (3.I.5.a). U.S. Air Force coating removal requirements include: Substitute for Methylene Chloride Paint Strippers (449); Decreased Waste Generation From Plastic Media, Sand, Walnut Hull, and Other Blasting Depaint Operations (808); and New Paint-Stripping Methods Have to Be Identified to Reduce Hazardous Waste and Cost (814). It should be noted that all of these requirements are considered high ranking needs within their respective service.

As an environmentally preferred coatings removal process, the FLASHJET® process eliminates the use of HAP chemicals and blast media. The FLASHJET® process does not use any hazardous materials during the coating removal stage, thus minimizing the potential for hazardous airborne dust particulates during operations.

1.3 Objectives of the Demonstration

There were four objectives of this demonstration/validation. The first objective was to successfully demonstrate the FLASHJET® process removing greater than 80% of the external coated surface area on various rotary wing and ground/fighting vehicle equipment including one SH-60 Seahawk, seven off-aircraft components from the CH-53, and one M113 Armored Personnel Carrier (APC). The FLASHJET® process had been tested extensively on small aircraft components during early research efforts specifically for the acceptance for U.S. Navy and U.S. Air Force fixed wing aircraft but this effort demonstrated the process on fully assembled rotary wing and ground/fighting vehicle applications. The second objective was to further qualify the FLASHJET® process via the FLASHJET® Qualification Testing Program in which each participating service developed their own high cycle fatigue testing acceptance criteria. Results of these tests would determine if the FLASHJET® process caused any fatigue failures from potential high substrate temperatures. The third objective was to calculate an

estimated life cycle cost per square foot for the FLASHJET® process for the tested equipment. At the conclusion of each equipment demonstration, data from each demonstration were incorporated into the Environmental Cost Analysis Methodology (ECAM) cost estimating tool to determine if the FLASHJET® process was more cost effective to implement than other approved coating removal processes. The final objective was to gather process application information that can assist the end user following transfer of the FLASHJET® process to DoD installations.

This demonstration/validation was conducted into two segments. The first segment evaluated the effectiveness of the FLASHJET® process on rotary wing aircraft equipment including CH-53 off-aircraft components and one SH-60 Seahawk and on a M113 APC ground/fighting vehicle. The second segment evaluated high cycle fatigue conditions on Aluminum specimens to further qualify the FLASHJET® process on rotary wing equipment for the three participating services.

1.4 Regulatory Issues

Large quantities of hazardous waste are commonly generated by DoD depot-related activities. Wastes associated with coating removal operations include the disposal of methylene chloride from chemical coating removal operations and media waste from a variety of blasting processes. Waste disposal quantities are commonly found on the installation's TRI Report. As stated earlier approximately 20% of the 1994 TRI figures come from coating removal activities.

Coating removal operations are impacted by a number of regulations including the Clean Water Act (CWA), the Clean Air Act (CAA), and the Resource Conservation and Recovery Act (RCRA). Washing surfaces following coating removal operations can generate quantities of wastewater contaminated with methylene chloride or media and coating residue. Discharging wastewater with traces of hazardous waste can result in a direct violation of the CWA. The most common regulation associated with coating removal operations is the CAA, including the recent efforts to minimize the use of HAPs such as methylene chloride. The RCRA directly regulates disposal of wastes generated by coating removal operations. The RCRA regulates how and where coating removal waste can be disposed and transported as well as any future liabilities resulting from environmental damage. Chemical and mechanical coating removal operations also require consideration for worker protection and training under the Occupational Safety and Health Act (OSHA).

The FLASHJET® process is not specifically regulated under current federal or state, environmental, safety, and health standards. The process uses no hazardous media and the waste generated is limited to coating residuals only, which typically is a non-hazardous solid waste. The automated system does not require direct worker involvement so safety and health risks are minimized. Some concern has been raised with the use of carbon dioxide gas in the FLASHJET® process as carbon dioxide has been targeted as a potential greenhouse gas contributing to global warming. The carbon dioxide used in the FLASHJET® process is effluent gas from other manufacturing operations and landfills that would otherwise be released to the atmosphere. Therefore, no additional carbon dioxide gas is produced specifically to support the FLASHJET® process.

1.5 Stakeholder/End-User Issues

Since the initial start of this ESTCP project, the FLASHJET® process has increased in popularity among Program Managers and installations that perform coating removal operations within the DoD. Proponents of the technology are impressed with the limited operator involvement and low discounted payback periods.

A major concern with the FLASHJET® process by the end-user community is still the high cost for procuring a system at an installation. The current cost for one FLASHJET® system installed is $3.2M. Even though the process has a high acquisition cost, an installation that purchased a FLASHJET® system will see significant cost avoidances after a few years of operation while maintaining a continuous workload.

1.6 Previous Testing of the Technology

The FLASHJET® process has evolved over ten years of research and development. In a 1987 Producibility, Reliability, Availability, and Maintainability (PRAM) study conducted at the Sacramento Air Logistics Center, the U.S. Air Force investigated the use of the xenon-flashlamp coatings removal technology as an environmentally preferred method for removing coatings from aircraft. The xenon-flashlamp proved to be successful but some issues needed to be addressed. Effluent ash generated in this process was not being contained and the temperature of the substrate was extremely high. Although this technology removed coatings from substrates, further research to lower substrate temperatures was needed prior to technology acceptance. In 1990 the U.S. Air Force conducted another PRAM study to evaluate the carbon dioxide pellet blasting technology at the Warner-Robins Air Logistics Center. At the conclusion of this study, it was determined that the carbon dioxide pellet blasting technology was an effective method for removing coatings but posed potential damage to composite substrates. Although the technology removed coatings, more research on minimizing substrate damage was needed to gain acceptance. Soon after the carbon dioxide pellet blasting results were available, a team of engineers from the McDonnell Douglas Corporation, Maxwell Laboratories, and Cold Jet, Incorporated combined these two coating removal technologies into one process. A small 3" prototype xenon-flashlamp/carbon dioxide pellet blasting system was originally developed and the FLASHJET® coatings removal process evolved.

The Warner-Robins Air Logistics Center took the lead within the DoD and funded a proof-of-concept prototype system to demonstrate the xenon-flashlamp/carbon dioxide pellet blasting technology. This prototype system consisted of a 6" FLASHJET® stripping head and successfully stripped the topcoat from a boron/epoxy F-15 vertical stabilizer without damage to the substrate. This was the initial indicator that the FLASHJET® coatings removal process was safe for stripping composite substrates.

Further testing was conducted through funding by the Strategic Environmental Research and Development Program (SERDP). This project titled "Aircraft Depainting Technologies" (PP-081) further validated the FLASHJET® coatings removal process by conducting fatigue tests on metallic and composite fixed-wing aircraft substrates. Favorable results from this testing led to the approval of the FLASHJET® process for metallic fixed wing aircraft within the U.S. Navy in

July 1997 and for composite fixed wing aircraft within the U.S. Navy in April 2000. Also developed under this SERDP project was a mobile manipulator for the FLASHJET® stripping head. The system resembled aircraft de-icing operations where the stripping head could be attached to a manipulator arm and moved directly up to the equipment for operator controlled coating removal operations. Additional information regarding this SERDP project can be found at the following web site: www.serdp.org.

2. Technology Description

2.1 Description

The FLASHJET® coatings removal process involves the use of two coating removal technologies combined into one process. These technologies include the use of a xenon-flashlamp and a continuous stream of carbon dioxide pellets. An effluent capture system collects all the effluent ash and organic vapors. Effluent ash is captured by a series of high efficiency particulate air (HEPA) filters and organic vapors are processed through an activated charcoal tank. The FLASHJET® system is made up of six components including the flashlamp and stripping head, the manipulator robotic arm, the computer processed cell controller, the effluent capture system, the carbon dioxide pelletizer, and the flashlamp power supply. The manipulator robotic arm can either be operated on a fixed gantry system or by using the mobile manipulator that was developed under the SERDP program.

The xenon-flashlamp is the primary coating removal stage in the FLASHJET® process. The xenon-flashlamp contains low-pressure xenon gas and creates a high intensity flash that is directly reflected to the substrate ablating the coating from the surface. Pulsed light energy generated from the xenon-flashlamp pulses 4 to 6 times per second. The amount of coating ablated is directly proportional to the amount of energy processed into the system. As mentioned, the FLASHJET® process can be controlled to remove as little as 0.001" of coating and as much as 0.004" of coating during one pass. This control factor can be an asset if topcoat removal is required while leaving the underlying primer on the substrate.

A continuous stream of recycled carbon dioxide pellets completes the second stage of the process. This continuous stream has two purposes. First, the continuous stream cools and cleans the substrate, assisting in keeping the substrate at an acceptable temperature while the xenon-flashlamp ablates the coating. Additionally, the pellet stream keeps the flashlamp clear of any coating forcing the coating away from the flashlamp and towards the effluent capture system. All carbon dioxide used during the FLASHJET® process is captured from other industrial type sources, converted into liquid carbon dioxide, and reused in this process, thus not emitting any additional carbon dioxide into the atmosphere.

The effluent capture system collects all the effluent ash and organic vapors generated during ablation. Effluent ash is vacuumed into the capture system, separated by size in a particle separator, and then captured in a series of HEPA filters. Organic vapors are captured and

processed through an activated charcoal tank and emitted into the atmosphere with less than 5 parts per million light hydrocarbon emission.

Figure 1 provides a general overview of the FLASHJET® process. The yellow light details the pulsed light energy generated from the xenon-flashlamp. The light is reflected down to the substrate via a polished reflector located directly behind the flashlamp. The blue stream coming from the rear of the stripping head shows the recycled carbon dioxide pellet stream that cools and cleans the substrate along with sweeping away any of the ablated coating. The green stream details all of the ablated coating and organic vapors generated during the ablation process. This stream is vacuumed into the effluent capture system. Please note that that this picture does not fully represent the operation of the FLASHJET® process. The optimal stand-off distance is 2.19" from the surface of the substrate. Please note that this picture was developed for information purposes only. The standoff distance in this picture is not the actual standoff distance during operation of the system.

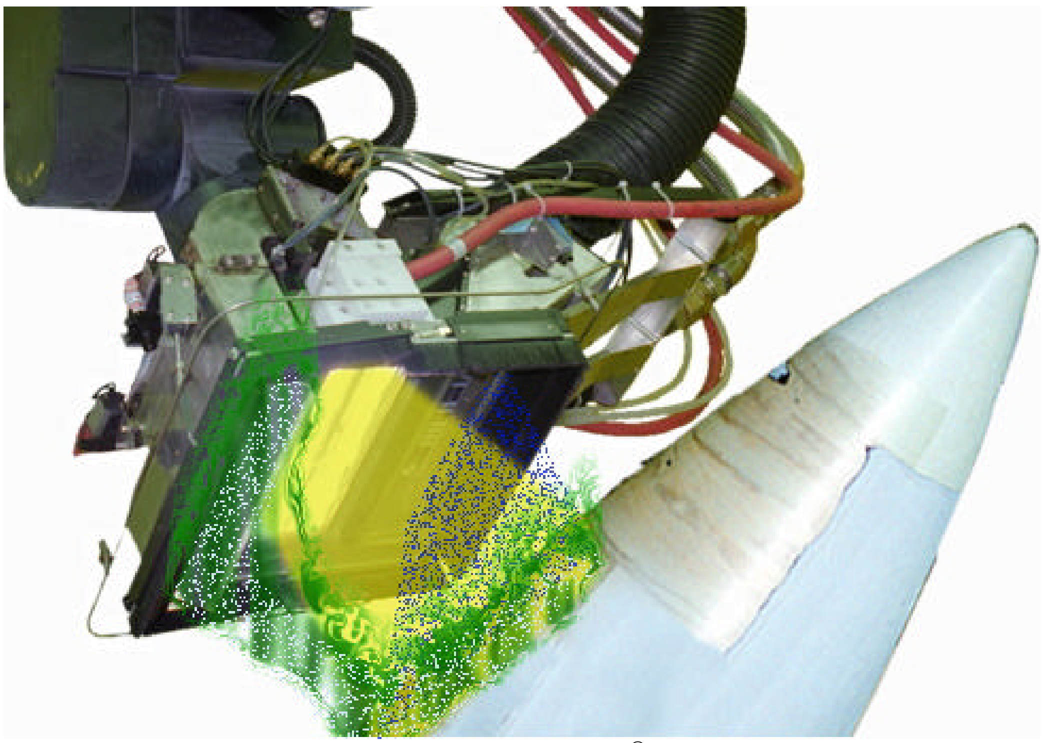

Figure 1: The FLASHJET® Process

Figures 2-5 contain pictures of the FLASHJET® system.

Figure 2: Effluent Capture System With CO_2 Tank

Figure 3: Computer Processing Cell Controller

Figure 4: FLASHJET® Power Supply

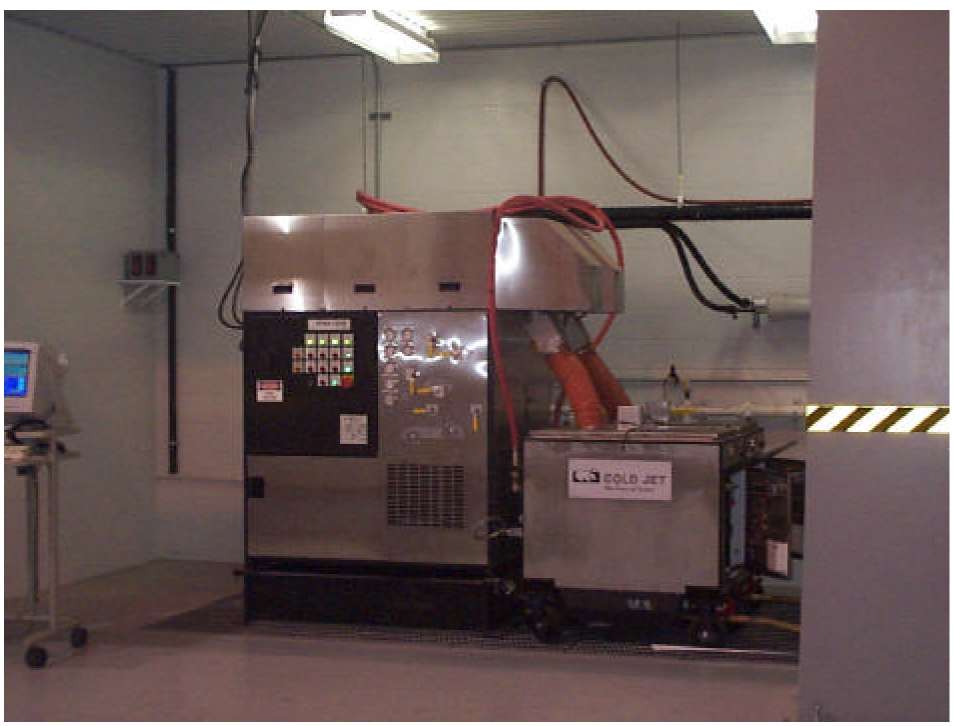

Figure 5: CO_2 Pelletizer

2.2 Strengths, Advantages, and Weaknesses

The FLASHJET® coatings removal process has several advantages over other traditional coating removal technologies. The greatest advantage of the FLASHJET® process is the small quantities of waste generated. The FLASHJET® process uses no hazardous media during coating removal operations. Eliminating the media from the process greatly reduces the amount of waste generated. The only waste generated is the spent HEPA filters that accumulate the effluent ash generated during the process. Compared to common media blasting and chemical coating removal operations used at depots, the FLASHJET® process has the potential to substantially reduce the amount of coating removal waste generated at a depainting facility.

Another advantage the FLASHJET® process has over other traditional coating removal technologies is the reduced manpower requirement for operating the system. Other traditional coating removal processes are very labor intensive and also require operators to wear personal protective equipment which can decrease coating removal efficiency.

The FLASHJET® process also has faster coating removal strip rates than other traditional coating removal technologies. In optimal conditions (i.e., flat surfaces), the FLASHJET® process can remove as much as 4 ft^2 per minute while other processes usually only remove up to 1 ft^2 per minute. This faster coating removal strip rate allows for more equipment to be processed increasing output requirements.

The main disadvantage of the FLASHJET® process is the high acquisition cost. The current cost for one FLASHJET® system is $3.2M, not including the cost of retrofitting an existing structure or constructing a new building. However compared to other coatings removal processes, the FLASHJET® process has the potential to yield the most attractive economic benefits. To show the potential cost savings, a life cycle cost comparison was conducted by the former McDonnell Douglas Corporation in 1996 for the F/A-18A Fighter Aircraft. At the conclusion of the study, the FLASHJET® process was calculated to have an estimated life cycle cost per square foot of $2.89. Plastic media blasting was calculated to be $15.40 per square foot and chemical depainting was calculated at $33.61 per square foot. Although the FLASHJET® process has a high acquisition cost, it is offset by an attractive life cycle cost. Additional economic analyses have been conducted since this 1996 McDonnell Douglas Corporation F/A-18A economic analysis. Three economic analyses conducted during this demonstration/validation can be found in Appendix D, E, and F of this report. A summary of these analyses can be found in Section 6, Cost Assessment, of this report.

Another disadvantage of the FLASHJET® process is that the system is not able to access tight corners due to the current configuration of the FLASHJET® stripping head. The FLASHJET® stripping head is approximately 15” wide with a 12” stripping index or stripping path, which includes the xenon-flashlamp, the carbon dioxide pellet stream nozzles, the containment shroud, and the bump sensors. A secondary coating removal process will be needed for areas inaccessible to the FLASHJET® stripping head. This problem, however, is commonly found with other coating removal technologies. Also this may cause the life cycle cost per square foot for the FLASHJET® process to increase slightly due to the capital cost of the complementary technology and other costs including labor and hazardous material disposal. Currently the

ESTCP is funding a project to demonstrate/validate a portable laser coating removal system (ESTCP Project: PP-200027) that can complement the FLASHJET® process as a secondary coating removal process.

2.3 Factors Influencing Cost and Performance

The major factor influencing the cost of the FLASHJET® process is cost for procuring and implementing a system. The current cost for a FLASHJET® system is $3.2M. As stated earlier, installations that have a continuous workload will experience significant cost avoidances by implementing the FLASHJET® process over their current coating removal process. Some factors for cost avoidances include the limited waste disposal requirements, limited operator requirements, and no requirement for purchasing associated blast media.

The major factor influencing the performance of the FLASHJET® process is directly attributed to the size of the FLASHJET® stripping head and its problem for negotiating into tight corners. The standard 12" stripping index head is optimal for both flat and round surfaces but the stripping head cannot negotiate into tight corners. The stripping index is defined as the point to point distance the FLASHJET® stripping head can depaint during one pass. For this reason a secondary coating removal technology may be required to access the areas where the FLASHJET® process cannot reach.

3. Site/Facility Description

3.1 Background

The selection of sites for this demonstration/validation was limited to locations where existing FLASHJET® systems were available. Three sites hosted different segments of this demonstration/validation and all systems were operated using the fixed gantry setup.

3.2 Site/Facility Characteristics

The Boeing Company's St. Louis, MO FLASHJET® Stripping Cell hosted the CH-53 off-aircraft component testing from February to March 1999 and also hosted the panel specimen stripping for all phases of the FLASHJET® Qualification Testing Program. This FLASHJET® system was installed for small component coating removal and was the first FLASHJET® fixed gantry system built. Figures 6 and 7 show some of the CH-53 off-aircraft component testing that was conducted in St. Louis, MO.

Figure 6: CH-53 Cargo Ramp Prior To Stripping

Figure 7: CH-53 Auxiliary Fuel Tank After Stripping

The Boeing Company's Mesa, AZ Apache FLASHJET® Paint Stripping Facility hosted the SH-60 Seahawk demonstration from October to December 1999. This facility is primarily used for Apache topcoat coating removal in the Apache AH-64A to AH-64D modification program. This facility has been in use since mid 1996 and has stripped over 200 Apache AH-64A helicopters. Figures 8 and 9 show some of the testing that was conducted in Mesa, AZ.

Figure 8: SH-60 Belly Of Aircraft After Stripping

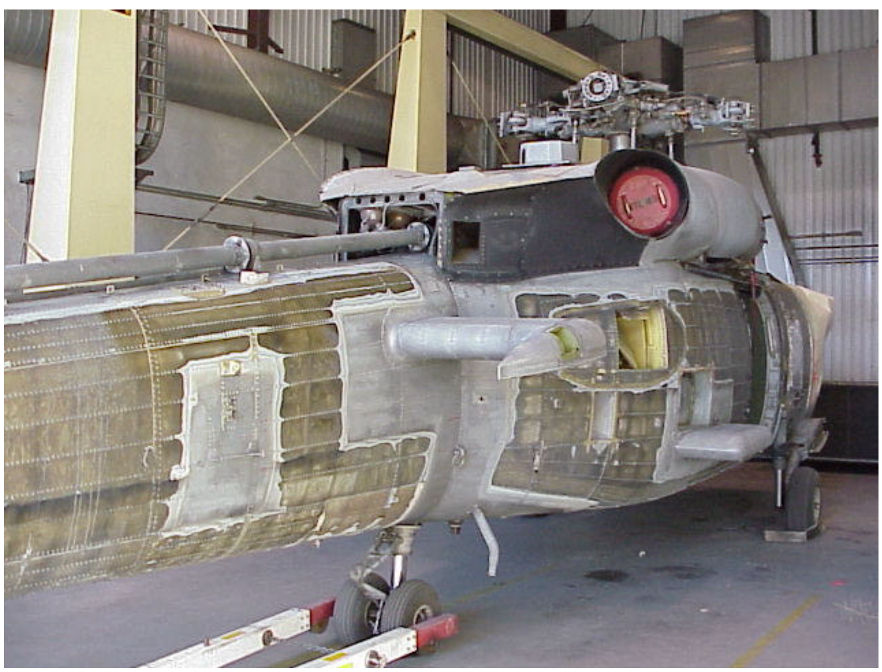

Figure 9: SH-60 Sections Stripped Down To Primer

The Corpus Christi Army Depot (CCAD) hosted the M113 APC demonstration in May 2000. The CCAD installed a FLASHJET® system to replace their media blasting process for rotary wing aircraft. CCAD is planning to use the FLASHJET® system on rotary wing aircraft as large as the CH-47 Chinook. Figures 10 and 11 show some of the testing that was conducted at CCAD.

Figure 10: Side Of M113 After Stripping


Figure 11: M113 Side During Stripping Operation

4. Demonstration Approach

4.1 Performance Objectives

The primary performance objective of this demonstration was to remove greater than 80% of the exterior coated surface area without causing damage to the underlying primer and substrates from military equipment using the FLASHJET® process. Secondary performance objectives included testing rotary wing aircraft type substrates that are subject to high-cycle fatigue conditions and verifying that process costs including life cycle costs, operation and maintenance requirements, and production rates will not impact facility resources or mission readiness.

4.2 Physical Setup and Operation

The demonstration was conducted at the three sites including at The Boeing Company's AH-64A Apache FLASHJET® Paint Stripping Facility in Mesa, AZ; The Boeing Company's FLASHJET® Paint Stripping Cell in St. Louis, MO; and the CCAD FLASHJET® facility. All FLASHJET® systems required no additional setup, instrumentation, or utilities for the purposes of this demonstration. The test schedule was coordinated with The Boeing Company and CCAD personnel based on the facility output needs. Standard operating procedures were followed to complete the test, using personnel trained in the operation of the system. The standard operating procedures must be developed for each site as operating procedures are site specific.

4.3 Testing Procedures

Before each piece of equipment was evaluated using the FLASHJET® process, the component or section was visually inspected for any damage possibly caused during the shipping of the specimen. Upon completion of the visual inspection, the coating thickness of the specimen was measured and recorded. Measuring the coating thickness gave the FLASHJET® operators an idea of how many strip passes would be required to remove the topcoat from a given section of the specimen.

Scan paths were then programmed into the computer process cell controller for each piece of equipment. The time required to program each section of the specimen was documented and totaled up at the end of the programming process. This time factor was included in the total estimated time required to depaint a given specimen.

Before the demonstration/validation began, stakeholder representatives from the three participating services developed a Joint Test Protocol (JTP) capturing the minimum requirements necessary to validate the FLASHJET® process on the selected equipment. The entire JTP can be found in Reference #3 as the JTP was an appendix to the demonstration plan.

Using the Data Sheet described in the JTP, the following data was recorded during the coating removal demonstration: total time to strip the section; stripping index; standoff distance of the stripping head; input voltage; stripping rate; flash frequency; and number of strip passes. All

data was compiled in using either the Data Sheet or using an abbreviated table that highlighted all of the coating removal data detailed above.

As detailed in the JTP, two separate testing programs were conducted in this demonstration/validation. Effectiveness testing and the FLASHJET® Qualification Testing Program further analyzed the FLASHJET® process in a test and evaluation environment. Effectiveness testing focused on three areas: coating removal; selective coating removal; and strippable area assessment. Results from all demonstration equipment were evaluated against those criteria. In the FLASHJET® Qualification Testing Program, fatigue specimen data were evaluated on a specific phase basis. Four separate phases were conducted in this testing program in order to meet the specific requirements set forth by each participating service.

4.4 Evaluation Procedures

Each depainted component or specimen was visually inspected for any damage by an evaluation team consisting of independent evaluators and quality assurance personnel. Any damage possibly caused by the FLASHJET® process was noted and damaged parts were replaced if required.

5. Performance Assessment

5.1 Performance Data

Performance data from all testing programs were compiled using the Data Sheets or an abbreviated table capturing the required data specified in the JTP. All data were evaluated by materials and/or structural engineers responsible for approving the technology for implementation. Pre-testing acceptance criteria, the minimum requirements necessary for technology approval, was determined by a group of technical representatives from the three services and included Program Managers of tested equipment.

The results from the Effectiveness Testing for the demonstration equipment are as follows (taken from the Joint Test Report – Aviation located in Appendix B). Also included in Appendix B is a summary of the number of passes required to depaint a given section on the demonstration equipment.

<u>CH-53 Off-Aircraft Component Testing</u>

In accordance with Section 3.1.1 of the JTP, all stripped sections were visually inspected to determine if the FLASHJET® process caused any physical damage to the substrates. Seven off-aircraft components were evaluated in this phase of testing including the cargo ramp, cargo door, auxiliary fuel tank, pylon, main rotor blade (Titanium), upper personnel door, and lower personnel door. All seven off-aircraft components were visually inspected and no damage to the stripped substrates was found.

In accordance with Section 3.1.2 of the JTP, all stripped sections were inspected to determine if the FLASHJET® process removed the topcoat while leaving the underlying primer. All sections were stripped down to the primer and passed this requirement.

In accordance with Section 3.1.3 of the JTP, to meet the minimal acceptance criteria requirement at least 80% of the external coated surface area would need to be removed. The following table provides the visual depaint results for the CH-53 off-aircraft component testing.

Table 1: CH-53 Off-Aircraft Component Visual Depaint Results

Test Part	Visual Depaint Results (%)
Cargo Ramp	98
Cargo Door	98
Auxiliary Fuel Tank	98
Pylon	90
Personnel Doors	95
Main Rotor Blade	91

All of the CH-53 off-aircraft components passed the effectiveness testing requirement.

SH-60 Seahawk

In accordance with Section 3.1.1 of the JTP, all sections of the SH-60 were visually inspected for possible substrate damage caused by the FLASHJET® process. One section of the aircraft was found to have substrate damage potentially caused by excessive heat buildup. On the back of this section, there was "bondo" like material which possibly caused the panel to heat up. Fortunately this panel was not flight critical and was replaced. After the panel was replaced, the aircraft was re-inspected and no further problems were found.

In accordance with Section 3.1.2 of the JTP, all sections were visually inspected to determine if the FLASHJET® process removed only the topcoat while leaving the underlying primer. Each stripped section was inspected and the primer was visible thus passing this test requirement.

In accordance with Section 3.1.3 of the JTP, at least 80% of the external coated surface area needed to be removed using the FLASHJET® process. Because of the coating removal limitations set by the Naval Air Systems Command (further described in Appendix B), only approximately 60% of the aircraft could be stripped using the FLASHJET® process. The technical stakeholders agreed that for this portion of the demonstration/validation that the 80% coating removal acceptance criteria would be evaluated on the allowable 60% surface area of the SH-60 Seahawk. Each of the fifty-three scan/strip paths far exceeded the 80% surface area test. It was estimated that greater than 98% of the allowable external coated surface area was removed using the FLASHJET® process. Only minimal hand sanding was required in certain coated areas that were not removed.

All aviation demonstration results, both equipment and FLASHJET® Qualification Testing Program, can be found in the Joint Test Report – Aviation located in Appendix B of this report.

References #1 and #7 contain more information on the CH-53 off-aircraft component testing and Reference #10 contains additional information on the SH-60 Seahawk evaluation

M113 Armored Personnel Carrier

Section 3.1.1 of the JTP specified that all coating (both primer and topcoat) must be removed with no damage to the underlying substrate. Front sections of the M113 APC were evaluated against this acceptance criteria. All sections with complete coating removal were visually evaluated for damage to the underlying substrate. No sections showed signs of substrate damage. The acceptance criteria for Section 3.1.1 was met.

Section 3.1.2 of the JTP specified for only topcoat removal with no damage to the underlying primer. The two sides of the M113 APC were visually evaluated against this acceptance criteria. Both sections were stripped cleanly to the primer and showed no signs of damage to the underlying primer. The acceptance criteria for Section 3.1.2 was met.

Section 3.1.3 of the JTP specified that at least 80% of the equipment's external coated surface area must be removed using the FLASHJET® process. In this demonstration, approximately 50% of the external coated surface area was stripped due to some stripping limitations. Some limitations included stripping head spacing limitations due protrusions on the buggy the M113 APC was resting on and the size of the digital camera that was installed on the front of the FLASHJET® stripping head. Since only 50% of the external coated surface area was stripped using the FLASHJET® process, this did not meet the acceptance criteria for 3.1.3. It should be noted that engineering design changes can be made to the stripping head that would allow for more coated surface area, both internal and external, to be removed using the FLASHJET® process.

FLASHJET® Qualification Testing Program

The FLASHJET® Qualification Testing Program consisted of high cycle fatigue type testing to simulate fatigue conditions experienced by rotary wing aircraft. This program consisted of two phases which captured the requirements for the participating services.

Phase I of the FLASHJET® Qualification Testing Program consisted of three sub-phases. Phase Ia evaluated the effects of the FLASHJET® process on both 2024-T3 and 7075-T6 Aluminum substrates that measured 0.016" in thickness. The purpose of this phase was to determine if the FLASHJET® process would harm thin skin Aluminum substrates on the SH-60 Seahawk. Results were favorable for the 2024-T3 however for the 7075-T6 there was an issue which required further evaluation.

Having faced a problem with Phase Ia, additional evaluation was required in order to gain approval to evaluate the FLASHJET® process on a SH-60 aircraft. Phase Ib covered additional testing for 7075-T6 Aluminum but at a thickness of 0.025". Test results showed no potential fatigue effects from the FLASHJET® process and approval was granted to evaluate the FLASHJET® process on an operational SH-60 Seahawk.

Phase Ic covered the requirements for qualification of the FLASHJET® process for Army rotary wing aircraft. In this phase both 2024-T3 and 7075-T6 Aluminum 0.025" thick specimens were

evaluated for life cycle fatigue effects. All of the Army testing showed no significant fatigue effects from using the FLASHJET® process on substrates commonly found on rotary wing aircraft and official Army approval for using the FLASHJET® process is currently being drafted through the U.S. Army Aviation and Missile Command.

Phase II measured the potential life cycle fatigue effects on Air Force and Navy substrates using a different preparation method than that of the Army in Phase Ic. Results from these tests showed no potential fatigue effects from using the FLASHJET® process and a specification for using the FLASHJET® process is currently being drafted for full approval for use within the Navy and Air Force.

5.2 Data Assessment

All data was compared to predetermined acceptance criteria that was stated in the JTP. Acceptance criteria for the FLASHJET® Qualification Testing Program could not be predetermined due to baseline criteria in each phase being unknown until all baseline testing data was compiled. This baseline data was known as Condition A where either Condition B or Condition C was evaluated against Condition A data. Refer to Appendix B for more information on the FLASHJET® Qualification Testing Program Condition A data.

All results from the demonstration equipment provide a realistic assessment of how the FLASHJET® process would work in an operational environment at installations that contain coating removal operations. In fact, when the technology is implemented at an overhaul installation, coating removal subject matter experts believe that the FLASHJET® process will be able to remove more coated surface area because most equipment will be fully disassembled and will contain less protrusions on the substrates.

5.3 Technology Comparison

The FLASHJET® process was compared to other traditional coating removal technologies currently operated at DoD installations. For the rotary wing applications, the FLASHJET® process was compared to media blasting. For the M113 APC, the FLASHJET® process was compared to the combination of stainless steel shot and garnet blasting.

The significant advantages of using the FLASHJET® process over other traditional coating removal technologies include a faster coating removal strip rate, decreased operator requirements, and the limited quantity of hazardous waste generated in the process. Other traditional coating removal technologies typically only remove approximately 1 ft^2 per minute while the FLASHJET® process can remove up to 4 ft^2 per minute. The FLASHJET® process allows for minimal operator involvement as the process is fully robotic. Other traditional coating removal processes require a number of operators to complete the process. Finally the FLASHJET® process only generates effluent ash during coating removal while other coating removal processes accumulate not only coating waste but also media waste which is used to remove the coating. All of these factors significantly reduce the total cost for coating removal operations.

6. Cost Assessment

6.1 Cost Performance

In previously conducted economic analyses comparing the FLASHJET® process to other traditional coating removal processes, the FLASHJET® process showed favorable economic advantages over the other traditional coating removal technologies. To further validate this theory, additional economic analyses were conducted at the end of the CH-53 Off-Aircraft Component, SH-60 Seahawk, and the M113 APC testing using the ECAM economic analysis tool. Results from all analyses can be found in the Cost and Performance Report which can be found at the following site: www.estcp.org.

Two separate economic analysis scenarios were calculated for the CH-53 and the SH-60 demonstrations. In the CH-53 demonstration, Scenario 1 took actual data from the demonstration/validation and assumed that the installation considering the FLASHJET® process has already purchased a media blasting booth (thus considered a sunk cost). In this scenario, the discounted payback period was compared between the FLASHJET® process and media blasting. In Scenario 2, the installation is considering purchasing either the FLASHJET® process or media blast booth for depainting operations and the net present value after a 15 year period of the two technologies was compared. Both scenarios assume that a total of 120 aircraft where each aircraft contains six CH-53 off-aircraft components will be stripped each year. Reference #6 contains more information on the CH-53 off-aircraft component economic analysis. In the SH-60 demonstration, Scenario 1 uses actual test data from the demonstration/validation taking into account the 60:40 ratio of FLASHJET® to hand sanding. Both the media blasting and FLASHJET® process are new technologies therefore initial installation costs are not sunk. In Scenario 2, the technologies are again compared but this time it was assumed that a 95:5 ratio FLASHJET® to hand sand ratio is used which can be typically found at major depainting installations. Both scenarios assume that 120 SH-60 Seahawks will be stripped each year and the installation is considering either installing the FLASHJET® process or media blasting. In both SH-60 scenarios the net present value of the technology after 15 years was compared. Reference #8 contains more information on the SH-60 Seahawk economic analysis.

Tables 2 and 3 show the estimated costs for operating the FLASHJET® process for rotary wing aircraft using the assumptions in Scenario 2 of the CH-53 and SH-60 ECAM analyses. Operation and maintenance costs are estimated annual costs. Additional cost information can be found in the Rotary Wing Cost and Performance Report.

Table 2: CH-53 (Scenario 2) Direct Process Costs

Direct Process Costs – CH-53 (Scenario 2)			
Startup Costs		**Operation and Maintenance**	
Procure Equipment	$3.3M	Labor	$272.8K
Training	$22.1K	Waste Management	$3.5K
Permitting	$9K	Utilities	$27.6K
1X Program	$3.8K	Direct Materials	$95.6K
		Health and Safety	$1.3K

Table 3: SH-60 (Scenario 2) Direct Process Costs

Direct Process Costs – SH-60 (Scenario 2)			
Startup Costs		**Operation and Maintenance**	
Procure Equipment	$3.3M	Labor	$115.5K
Training	$1.9K	Waste Management	$2.7K
Permitting	$5K	Utilities	$25K
1X Program	$4K	Direct Materials	$27.9K
		Health and Safety	$1.5K
		Refresher Training	$1.9K

Table 4 shows the estimated costs for operating the FLASHJET® process for ground/fighting vehicles along with using the hand held laser as a complementary technology. Operation and maintenance costs are estimated annual costs. These data were taken from the M113 ECAM analysis and may vary by installation and weapon system. The calculations were based on 500 vehicles being stripped each year. Reference #11 contains additional information on the M113 economic analysis.

Table 4: M113 Direct Process Costs

Direct Process Costs – M113			
Startup Costs		**Operation and Maintenance**	
Procure Equipment	$3.3M	Labor	$280K
Secondary Process	$200K	Waste Management	$7.5K
Training	$3.2K	Utilities	$20K
Permitting	$5K	Direct Materials	$28.2K
1X Program	$1K	Health and Safety	$5K
		Refresher Training	$3.8K

6.2 Cost Comparisons to Conventional and Other Technologies

Traditional coating removal methods in the rotary wing aircraft area have been the use of methylene chloride and media blasting such as wheat or plastic media blasting. Despite the smaller capital investment required to install media blasting, the annual operating costs associated with the FLASHJET® process makes the FLASHJET® process the more cost effective choice. The FLASHJET® process was compared to media blasting which presently is the most common form of rotary wing aircraft coating removal. Tables 5 and 6 provide cost data for

comparing the FLASHJET® process to media blasting for the CH-53 off-aircraft component testing.

Table 5: CH-53 (Scenario 2) Initial Investment Costs

Initial Investment Costs – CH-53 (Scenario 2)		
Category	**Media Blasting**	**FLASHJET®**
Purchased Equipment	$2.5M	$3.2M
Training	$8.7K	$22.1K
Permitting	$5K	$9K
Programming	$0	$3.8K

Table 6: CH-53 (Scenario 2) Annual Operating Costs

Annual Operating Costs – CH-53 (Scenario 2)		
Category	**Media Blasting**	**FLASHJET®**
Process Materials	$688.9K	$95.6K
Utilities	$6K	$27.6K
Direct Labor	$407.2K	$272.8K
Waste Management	$138.5K	$3.5K
Health and Safety	$2K	$1.3K

Assuming a 15 year life cycle from the data in this CH-53 off-aircraft component analysis, the final results showed that the FLASHJET® process had a net present value of -$7,988,498 while media blasting had a net present value of -$17,178,463. The most significant factor for the FLASHJET® process being more economical was the savings in annual waste management and direct labor costs of the FLASHJET® process over media blasting operations.

Results from Scenario 1 of the CH-53 off-aircraft component analysis yielded a discounted payback period of 4.22 years if the FLASHJET® process was installed over the current media blasting operation. Results of this analysis can be found in Reference #2.

Similarly to the CH-53 off-aircraft component testing, media blasting again was used as the comparison coating removal technology for the SH-60 Seahawk economic analysis. Tables 7 and 8 provide cost data for comparing the FLASHJET® process to media blasting for the SH-60 Seahawk testing.

Table 7: SH-60 (Scenario 2) Initial Investment Costs

Initial Investment Costs – SH-60 (Scenario 2)		
Category	**Media Blasting**	**FLASHJET®**
Purchased Equipment	$2.0M	$3.2M
Training	$8K	$1.9K
Permitting	$5K	$5K
Programming	$0	$4K

Table 8: SH-60 (Scenario 2) Annual Operating Costs

Annual Operating Costs – SH-60 (Scenario 2)		
Category	**Media Blasting**	**FLASHJET®**
Direct Materials	$133.7K	$27.9K
Utilities	$13K	$25K
Direct Labor	$525.6K	$115.5K
Waste Management	$256.4K	$2.7K
Health and Safety	$18K	$3.4K

Assuming a 15 year life cycle from the data in this SH-60 Seahawk analysis, the final results showed that the FLASHJET® process had a net present value of -$5,312,485 while media blasting had a net present value of -$13,175,544. The most significant factors for the FLASHJET® process being more economical are the savings in annual waste management, direct labor, and direct material costs which are significantly higher for media blasting. Results from Scenario 1 can be found in Reference #8.

Traditional coating removal technologies used in the depainting of ground/fighting vehicles include the use of stainless steel shot blasting followed by garnet blasting for final coating removal. Another mechanical coating removal technology that is currently being evaluated is the use of the Waterjet technology. Both the stainless steel shot/garnet blast and the Waterjet technology were used as comparison technologies for the M113 APC economic analysis. Tables 9 and 10 provide cost data for comparing the FLASHJET®/hand held laser process to the stainless steel shot/garnet blast and robotic Waterjet processes for the M113 APC testing.

Table 9: M113 Initial Investment Costs

Category	Stainless Steel Shot/ Garnet Blast	Robotic Waterjet/ Hand Lance	FLASHJET®/HHL
Purchased Equipment	$0*	$2.3M	$3.5M
Training	$0	$3.2K	$3.2K
Permitting	$5K	$5K	$5K
Programming	$0	$0.3K	$0.3K

* Note – Cost considered sunk as installation has already purchased the steel shot/garnet blast system.

Table 10: M113 Annual Operating Costs

Category	Stainless Steel Shot/ Garnet Blast	Robotic Waterjet/ Hand Lance	FLASHJET®/HHL
Direct Materials	$403.8K	$27K	$28.2K
Utilities	$30K	$20K	$20K
Direct Labor	$280K	$440K	$280K
Waste Management	$90.3K	$7.5K	$7.5K
Health and Safety	$13.5K	$8.8K	$8.8K

Assuming a 15 year life cycle from the data in this M113 APC analysis, the final results showed that the FLASHJET® process had 8.50 year discounted payback period while the Waterjet/Hand Lance process had a 8.22 year discounted payback period. The payback periods for both the FLASHJET® process and the Waterjet process are much higher than that for rotary wing aircraft. Typically ground/fighting vehicle depainting operations require secondary coating removal technologies for complete coating removal and these additional technologies are quite expensive.

It is important to note that the discounted payback periods will be different at each location. This is mainly due to different labor rates at installations and the different environmental requirements that an installation must meet in order to maintain compliance.

6.3 Life Cycle Cost Per Square Foot Analysis

The third objective of this demonstration was to calculate a life cycle cost per square foot for all of the equipment in this demonstration/validation. Tables 11-13 show the approximate life cycle cost per square foot for the demonstrated equipment.

Table 11: CH-53 Off-Aircraft Component Life Cycle Cost Analysis

Scenario	Technology	Installation Cost	Annual Costs	~ Area (ft^2)	Total Depainted Each Year	LCC/ft^2
Scenario 1	Media Blasting	$40,000	$1,242,610	435	120	$23.86
	FLASHJET®	$3,281,904	$400,761	435	120	$11.87
Scenario 2	Media Blasting	$2,558,680	$1,242,610	435	120	$27.07
	FLASHJET®	$3,279,904	$400,761	435	120	$11.87

Table 12: SH-60 Life Cycle Cost Analysis

Scenario	Technology	Installation Cost	Annual Costs	~ Area (ft^2)	Total Depainted Each Year	LCC/ft^2
Scenario 1	Media Blasting	$2,048,150	$946,700	1500	120	$6.02
	FLASHJET®	$3,278,120	$400,315	1500	120	$3.44
Scenario 2	Media Blasting	$2,048,150	$946,700	1500	120	$6.02
	FLASHJET®	$3,278,920	$174,550	1500	120	$2.18

Table 13: M113 Life Cycle Cost Analysis

Technology	Installation Cost	Annual Costs	~ Area (ft^2)	Total Depainted Each Year	LCC/ft^2
Steel Shot/ Garnet Blast	$3,508,200	$817,840	350	500	$6.01
FLASHJET®/ Hand Held Laser	$3,476,520	$344,570	350	500	$3.29
Waterjet/ Hand Lance	$2,259,520	$476,340	350	500	$3.58

Data from these life cycle cost calculations were taken from actual demonstration results or by using best engineering judgment. The FLASHJET® process yields the lowest life cycle cost per square foot for each of the scenarios to include the M113 Armored Personnel Carrier demonstration which showed a slightly larger discounted payback period for the FLASHJET® process versus the Waterjet process.

7. Regulatory Issues

7.1 Approach to Regulatory and End-User Acceptance

Prior to each phase of the demonstration, environmental personnel from each facility hosting the demonstration reviewed the major environmental regulations that could have affected this demonstration. At all three locations, it was determined that the CAA, the OSHA, and the RCRA would directly affect this demonstration.

Under the regulations of the CAA, the locations hosting the demonstration may have been subject to a Title V Air Permit. This was the case for The Boeing Company's Mesa, AZ FLASHJET® facility. At the time of this demonstration, The Boeing Company in Mesa, AZ was covered under their existing Title V Air Permit. No additional CAA permits were required for this demonstration. The Mesa, AZ facility was also covered under the Maricopa County (AZ)

Air Permit. The Boeing Company Environmental Safety Office monitored the compliance of the FLASHJET® facility's emission levels for both permits. Since the facility has been in operation, no violations of any CAA permits have occurred. The Boeing Company's St. Louis, MO and the CCAD facilities are not located under Title V restrictions.

The OSHA requires that two operators be present during the operation of any robotic process. During each portion of the demonstration, two operators were present during operation of the FLASHJET® process. When operators were visually inspecting sections during the operation, the operators wore ultraviolet protective goggles and hearing protection due to the high intensity flashes and loud noise during the operation of the system. Operators that were not inside the stripping bay during operation were protected from the ultraviolet light and noise by being inside the operator control room that contained ultraviolet protected glass and sound proof insulation. Safety monitors at all three demonstration locations monitored OSHA requirements during the demonstration and no violations occurred. The FLASHJET® process also allows operators to use less personal protective equipment than other traditional coating removal technologies.

Before the HEPA filters could be disposed of in a solid waste landfill, the filters needed to be tested for toxicity characteristics via the EPA Method SW-846 Toxicity Characteristic Leaching Procedure test. At the two demonstration locations hosted by The Boeing Company, all spent HEPA filters were automatically disposed of as hazardous waste because it is more economical for The Boeing Company to just dispose of the filters in a hazardous waste landfill than testing the filters prior to disposal. Spent HEPA filters at the CCAD were tested for toxicity characteristics and the filters met acceptable solid waste landfill levels.

At the conclusion of the demonstration, no additional environmental regulations were found to be impacted as a result of the operation of the FLASHJET® process. The CAA, OSHA, and RCRA regulations would be applicable at any location where the FLASHJET® process would be in operation. For installations planning to implement the FLASHJET® process, it is necessary to work closely with the installation's environmental office so that all environmental regulations are considered.

8. Stakeholder/End-User Issues

Prior to the demonstration, the project's technical representatives determined what weapon system programs are affected by high quantities of hazardous waste generated from coating removal operations. The project's technical representatives decided to focus on rotary wing and ground/fighting vehicle applications which received concurrence from the ESTCP. Using the FLASHJET® process on U.S. Air Force and U.S. Navy fixed wing aircraft gained acceptance under the SERDP program and eventually led to qualifying the FLASHJET® process on fixed wing aircraft. Under the scope of this ESTCP project, the demonstration/validation of equipment not previously tested and accepted in previous programs would be examined.

As required by the ESTCP, a JTP was developed prior to the demonstration that covered all of the minimal requirements that a Program Manager would need prior to approving the use of the FLASHJET® process on their weapon systems. The project's technical representatives worked closely with the Program Managers and determined what requirements were mandatory to gain full acceptance. Rotary wing Program Managers requested that prior to granting approval for using the FLASHJET® process on their systems that a series of high cycle fatigue testing programs be initiated to determine potential fatigue effects of using the FLASHJET® process on thin skin Aluminum substrates. Prior to the one time depaint of a SH-60 Seahawk, the SH-60 Program Manager (PMA-299) requested that a high cycle fatigue testing program be initiated to determine if the process would cause any damage to the substrate after a one time depaint cycle. In Phase Ib of the FLASHJET® Qualification Testing Program, 0.025" 7075-T6 Aluminum substrates were examined for fatigue failures and no major problems were encountered. The technical stakeholders in the Army aviation community requested that a separate specimen preparation method be used during the Army fatigue testing portion of the program. In this program, all specimens were either drilled or cracked prior to the painting/depainting cycles.

Program Managers for ground/fighting vehicles did not have any safety related requirements. JTP requirements for ground/fighting vehicles required that the FLASHJET® process be able to remove more than 80% of the external coated surface area of the systems tested.

Most of the technical stakeholders who contributed to the development of the JTP were DoD Program Managers. By approving the completed JTP, they signified they would consider supporting the implementation of the FLASHJET® technology since it met the agreed-on acceptance criteria during its demonstration/validation. At the conclusion of this project, all technical stakeholders validated all testing data and a formal approval via drafting of process coating removal specifications are expected to be released by the summer of 2002 within the three participating services.

9. Technology Implementation

9.1 DoD Need

With the large quantities of hazardous waste generated and disposed of each year at major DoD installations housing coating removal operations, there is a tremendous need to implement a cost effective and environmentally preferred coating removal process. Even though the acquisition cost for implementing the FLASHJET® process is high, the attractive cost avoidances by implementing the FLASHJET® process outweigh the initial implementation cost.

Each service has expressed an interest in implementing the FLASHJET® process. The CCAD, the Naval Air Station – Kingsville, and the Naval Aviation Depot – Jacksonville have installed the FLASHJET® system are programming scan paths on equipment to be depainted.
The following table shows a quick breakdown of the major DoD painting/depainting installations by service.

Table 14: Depots Considering the FLASHJET® Process

Service	Depots (and Others) Considering FLASHJET®
Army	Anniston Army Depot CT and MO AVCRAD Fort Irwin
Navy	NADEP – Cherry Point NADEP – North Island
Air Force	Warner-Robins Air Logistics Center

9.2 Transition

The FLASHJET® process is fully ready for implementation at major DoD installations containing coating removal operations. The results from this demonstration were evaluated and validated by material and structural engineers when required, specifically for the results of the FLASHJET® Qualification Testing Program. All three participating services plan to increase their FLASHJET® process capabilities by allowing for the implementation of the process on rotary wing aircraft.

The current configuration of the FLASHJET® stripping head is satisfactory for all rotary wing aircraft. When rotary wing aircraft are to be stripped at a major installation containing coating removal operations, the entire airframe is disassembled and the fuselage is relatively smooth. For this reason, there is little need to reconfigure the FLASHJET® stripping head for rotary wing aircraft.

During the M113 APC demonstration, the FLASHJET® stripping head could not negotiate into areas where protrusions were encountered. For this reason, only approximately 50% of the external coated surface area of the hull was stripped using the FLASHJET® process. If the FLASHJET® process is to be implemented on ground/fighting vehicles, the configuration of the FLASHJET® stripping head must be changed. This item was brought to the attention of the proprietor of the FLASHJET® process. Flash Tech, Inc. states that a smaller FLASHJET® stripping head could be developed and tailored to fit the requirements of a given installation. Developing a site specific FLASHJET® stripping head could help to reduce the waste generated during secondary coating removal operations. The major element of a half size stripping head have been built and tested. Testing is scheduled for the Summer 2002.

For installations considering to implement the FLASHJET® process, a variety of funding avenues exist. Installations can choose to use installation base funds or program for funding in environmental program requirement project calls. It is suggested that if an installation is planning to implement the FLASHJET® process, that installation should start considering funding avenues as soon as the process is being considered. Installations planning to implement the FLASHJET® process should consider, if possible, retrofitting an existing facility at the installation to reduce potential construction costs. Leasing a FLASHJET® system is also another option.

Since the FLASHJET® process is a proprietary technology, the only avenue for implementing the technology is to contract directly with Flash Tech, Inc. The contracting process can take a very long time so it is suggested that installations considering to implement the technology work closely with their local contracting office to determine what requirements are necessary for contracting directly with Flash Tech, Inc. Flash Tech, Inc. has also established a working relationship with the Navy contracts office at Lakehurst. All services can utilize this contract vehicle. The point of contact at the Lakehurst Naval Air Station is Keith Davis at 732-323-2243.

10. Lessons Learned

Several observations were noted during each portion of the demonstration/validation. A listing of observations during each equipment phase is listed below.

CH-53 Off-Aircraft Component Demonstration:

- For any type of off-aircraft component being stripped using the FLASHJET® process, it is necessary to build component specific fixtures to hold the components in place during the stripping phase. During this demonstration, all off-aircraft components had to be clamped down during the stripping and some of the clamps hindered the strip paths.

SH-60 Seahawk Demonstration:

- When positioning the aircraft inside the stripping hangar, place all aircraft in the same spot each time. This will eliminate the need to re-program scan paths into the central computer and save time and money. When Apaches are stripped at the Mesa, AZ facility, positioned jacks are mounted to the floor and all aircraft are rolled onto those jacks putting the aircraft in the same location each time so that the operator does not need to program new scan paths every time a new aircraft rolls into the stripping bay.
- During this demonstration, the input voltage was set at a maximum of 2050 volts. The maximum capability of the FLASHJET® process is 2300 volts. Because the maximum power allowed for this demonstration was 2050 volts, it took much longer to strip the aircraft. Also because of the lighter color paint on the aircraft it was harder to strip the topcoat at the 2050 volts. Increasing the input voltage to the maximum 2300 volts for the first few passes would increase the stripping efficiency.
- For maximum stripping efficiency, a standoff distance of 2.19” is required. In order to completely meet this standoff distance, it is necessary to have a FLASHJET® system that has operational standoff sensors when programming scan paths. During this demonstration the FLASHJET® stripping head did not have operational standoff sensors when the operator was programming scan paths. Having operational standoff sensors will also decrease the time for programming scan paths into the central computer.
- Sections of the aircraft were not stripped due to protrusions on the frame of the aircraft. In the Apache AH-64A Modification Program when the FLASHJET® process is used to strip the fuselage, all antennas and other protrusions are removed from the aircraft. During this demonstration, the programmer had to skip over some sections of the fuselage due to

protrusions and those sections had to be hand-sanded. In order to maximize the efficiency of the FLASHJET® process for the H-60 aircraft, it is necessary to remove all protrusions.

- Approval is required to strip composite sections of the aircraft using the FLASHJET® process. In this demonstration, the Naval Air Systems Command limited the use of the FLASHJET® process on only Aluminum substrates with thicknesses greater than 0.025". Composite substrates were not allowed to be stripped in this demonstration. It is crucial that the necessary high cycle fatigue testing scenarios for composite substrates be conducted. Permitting the use of the FLASHJET® process on composite substrates will greatly reduce the man-hours required for stripping aircraft and will also reduce the life cycle cost per square foot.

M113 Armored Personnel Carrier Demonstration:

- When positioning the M113 APC or other ground/fighting vehicles inside the stripping bay, place all equipment in the same position each time. This will eliminate the need to re-program scan paths into the central computer. It is suggested that hydraulic jacks be used to lift up the equipment so that the maximum amount of surface area underneath the equipment can be stripped.
- To increase the amount of stripping area on ground/fighting vehicles, it will be necessary to use a smaller stripping head to strip areas around and over bulky protrusions. Flash Tech, Inc. can design a stripping head that will allow for stripping more surface area. Using a smaller stripping head can increase the stripped area percentage for both external and internal surface areas. A secondary coating removal process such as garnet blasting or a hand-held laser system will still be required for removing coated areas not capable of being stripped using the FLASHJET® process.
- For installations considering implementing the FLASHJET® process in humid environments, it maybe necessary to have a climate controlled stripping bay. During the demonstration at CCAD, high humidity caused the pelletizer to freeze up on several occasions. Also, after the stripping was completed, the stripping bay was covered with condensation. Condensation that built up on the effluent capture system eventually dropped to the floor. A climate controlled stripping bay will eliminate condensation buildup on the system during operation.

11. References

1. Breihan, David W. The Boeing Company. *Performance Report – FLASHJET® Paint Stripping Process on CH-53 Helicopter Parts as a part of the Environmental Security Technology Certification Program (ESTCP) – Demonstration and Validation*. Contract No. DACA31-98-R-0047-0001. April 1999

2. Concurrent Technologies Corporation. *Environmental Cost Analysis Methodology (ECAM) Handbook*. Environmental Security Technology Certification Program (ESTCP) Validation Tasks. Contract No. DAAA21-93-C-0046. Task No. 098. CDRL No. A013. January 1998

3. Hutchins, Dean W. U.S. Army Environmental Center. *Tri-Service Dem/Val of the Pulsed Optical Energy Decoating (FLASHJET®) Process for Military Application – Technology Demonstration Plan and Joint Test Protocol*. Version 4. October 2000

4. Kozol, Joseph and Hartle, Steven. Naval Air Warfare Center – Aircraft Division. *FLASHJET® Qualification Testing for Lifecycle Depainting of Rotary Wing Fuselage Skins*. December 2000

5. Mackenzie, Donald S. The Boeing Company. *Failure Analysis of Fatigue Test Specimens Subjected to FLASHJET®* . The Boeing Company Technical Memorandum Number: 254.99.0018.01. April 1999

6. Pavlik, Milissa B. The National Defense Center for Environmental Excellence (NDCEE) – Concurrent Technologies Corporation. *Tri-Service Demonstration and Validation of the FLASHJET® Process for Military Applications: CH-53 Off-Aircraft Component Economic Analysis*. Contract No. DAAA-21-93-C-0046. Task No. N126. CDRL No. A004. September 1999

7. Pavlik, Milissa B. The National Defense Center for Environmental Excellence (NDCEE) – Concurrent Technologies Corporation. *Tri-Service Demonstration and Validation of the FLASHJET® Process for Military Applications: CH-53 Off-Aircraft Component Test Report.* Contract No. DAAA-21-93-C-0046. Task No. N126. CDRL No. A003. September 1999

8. Stemniski, Peter M. Platinum International, Inc. *Environmental Cost Analysis Methodology – FLASHJET® Coating Removal Process on the SH-60 Seahawk Aircraft as a Part of the Environmental Security Technology Certification Program – Demonstration and Validation.* February 2000

9. Stemniski, Peter M. Platinum International, Inc. *Performance Report – FLASHJET® Coatings Removal Process on the M113 Armored Personnel Carrier as apart of the Environmental Security Technology Certification Program – Demonstration and Validation*. June 2000

10. Stemniski, Peter M. Platinum International, Inc. *Performance Report – FLASHJET® Coating Removal Process on the SH-60 Seahawk Aircraft as a Part of the Environmental Security Technology Certification Program – Demonstration and Validation.* February 2000

11. Stemniski, Peter M. U.S. Army Aberdeen Test Center. *Environmental Cost Analysis Methodology – FLASHJET® Coating Removal Process on the M113 Armored Personnel Carrier as a Part of the Environmental Security Technology Certification Program – Demonstration and Validation*. July 2000

Appendix A
List of Acronyms

APC	Armored Personnel Carrier
AVCRAD	Aviation Classification Repair and Depot
CAA	Clean Air Act
CCAD	Corpus Christi Army Depot
CWA	Clean Water Act
DoD	Department of Defense
ECAM	Environmental Cost Analysis Methodology
ESTCP	Environmental Security Technology Certification Program
HAP	Hazardous Air Pollutant
HEPA	High Efficiency Particulate Air
JTP	Joint Test Protocol
NESHAP	National Emission Standard for Hazardous Air Pollutants
OSHA	Occupational Safety and Health Act
PRAM	Producibility, Reliability, Availability, and Maintainability
RCRA	Resource Conservation and Recovery Act
SERDP	Strategic Environmental Research and Development Program
TRI	Toxic Release Inventory
VOC	Volatile Organic Compound

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Appendix B
Joint Test Report – Aviation

Appendix B of this Final Report contains the Joint Test Report for the rotary wing components of this ESTCP demonstration. This portion of the demonstration/validation was conducted in two sections. The first section covered actual demonstration/validation testing of the FLASHJET® process on CH-53 Off Aircraft Components and one operational SH-60 Seahawk. The second section covered the FLASHJET® Qualification Testing Program which attempted to further qualify the FLASHJET® process for rotary wing aircraft within the three services.

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Environmental Security Technology Certification Program (ESTCP)

Joint Test Report

For Validation of
An Alternative to Hazardous Media for
Depainting Activities on Military Applications
Using the FLASHJET® Coatings Removal Process:

CH-53 Off-Aircraft Components and SH-60 Seahawk

2 May 2001

PREFACE

This report was prepared by Peter M. Stemniski, P.E. of the U.S. Army Aberdeen Test Center. This report was prepared on behalf of, and under guidance provided by, the Environmental Security Technology Certification Program (ESTCP). The structure, format, and depth of the technical content of the report was determined by the ESTCP, Government contractors, and other Government technical representatives in response to the specific needs of this project.

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- Warner-Robins Air Logistics Center – Robins, GA
- Davis-Monthan Air Force Base – Tucson, AZ
- Corpus Christi Army Depot – Corpus Christi, TX
- Naval Aviation Depot – Cherry Point, NC
- Aviation Research Development and Engineering Center – Redstone Arsenal, AL
- U.S. Army Research Laboratory – Aberdeen Proving Ground, MD
- U.S. Pacific Fleet Helicopter Anti-Submarine Light Wing – San Diego, CA
- Army Acquisition Pollution Prevention Support Office – Alexandria, VA
- The Boeing Company – St. Louis, MO and Mesa, AZ
- Platinum International, Inc. – Alexandria, VA
- National Defense Center for Environmental Excellence – Johnstown, PA

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EXECUTIVE SUMMARY

In October 1997, the Environmental Security Technology Certification Program awarded the U.S. Army Environmental Center a project to demonstrate and validate the Flash Tech, Inc. (formerly The Boeing Company's) FLASHJET® Coatings Removal Process on military equipment, specifically on rotary wing and ground/fighting vehicle applications. The FLASHJET® process, originally patented by the McDonnell-Douglas Corporation, combines the xenon-flashlamp and carbon dioxide (dry ice) pellet blasting technologies into an environmentally acceptable coatings removal process.

Technical representatives from affected aviation rotary wing programs within the three services agreed to minimal testing requirements that would qualify the FLASHJET® process on selected aviation weapon systems. These requirements can be found in the Joint Test Protocol.

In this demonstration/validation, the FLASHJET® process was evaluated on CH-53 off-aircraft components and one fleet SH-60 Seahawk. Also included in this aviation portion of the demonstration was the FLASHJET® Qualification Testing Program which would determine if the operation of the FLASHJET® process would decrease the fatigue life of thin skin Aluminum substrates commonly found on rotary wing aircraft.

All demonstration equipment passed the requirements as depicted in the Joint Test Protocol. Results from the FLASHJET® Qualification Testing Program show that the FLASHJET® process does not cause fatigue failures on thin skin Aluminum substrates.

1. INTRODUCTION

The FLASHJET® process was developed in 1991 by a team of engineers from the McDonnell Douglas Corporation, Maxwell Laboratories, and Cold Jet, Inc. The FLASHJET® process combines the use of the xenon-flashlamp and carbon dioxide coatings removal technologies into one process. The process consists of six components including the flashlamp and stripping head, the manipulator robotic arm, the computer processing cell controller, the effluent capture system, the carbon dioxide pelletizer, and the power supply for the system.

A series of demonstrations occurred to further validate the FLASHJET® process on rotary wing applications. From February and March 1999 at The Boeing Company's FLASHJET® Paint Stripping Cell in St. Louis, MO, CH-53 off-aircraft components were evaluated using the FLASHJET® process including the cargo ramp, cargo door, auxiliary fuel tank, pylon, two personnel doors, and one main rotor blade. From October through December 1999, the FLASHJET® process was evaluated on an operational SH-60 Seahawk at The Boeing Company's Mesa, AZ Apache FLASHJET® Paint Stripping Facility. The main objective of these demonstrations was to successfully demonstrate the FLASHJET® process by removing a significant portion of the external surface area topcoat and leaving the underlying primer.

Another series of tests were conducted to determine if the FLASHJET® process would cause any fatigue damage to thin Aluminum substrates. Two phases of high cycle fatigue testing were conducted to meet coating removal acceptance requirements of the three participating services. These phases either qualified the FLASHJET® process for a one-time depaint or for over the total life cycle of a rotary wing aircraft.

2. PERFORMANCE AND TESTING REQUIREMENTS

A joint group led by the Environmental Security Technology Certification Program and consisting of technical representatives from the affected Department of Defense (DoD) Program Managers, Naval Air Systems Command, Warner-Robins Air Logistics Center, Aviation Research, Development and Engineering Center (AVRDEC), Corpus Christi Army Depot, and other government technical representatives identified engineering performance, and operational impact (supportability) requirements for depainting processes. This group then reached a consensus on tests to qualify potential alternatives against these technical requirements including procedures, methodologies, and acceptance criteria as applicable.

The FLASHJET® process was demonstrated and validated in two separate testing programs, effectiveness testing and qualification testing. The effectiveness testing program was conducted to evaluate the ability of the FLASHJET® process to remove coatings without damaging the substrate, to selectively remove topcoat layers only, and to reach intricate areas of the test specimen. Effectiveness tests were conducted on the CH-53 off-aircraft components and the SH-60 Seahawk. The FLASHJET® Qualification Testing Program was established to determine potential fatigue failures to thin Aluminum substrates possibly caused by the high temperatures encountered with the high intensity light flashes.

The following table represents the performance and test requirements from the Joint Test Protocol (JTP) for the aviation portion of the demonstration.

Table 1: Joint Test Protocol Performance and Test Requirements

Test Category	Test Name	JTP Section	Acceptance Criteria	References
Effectiveness Tests	Coatings Removal	3.1.1	Coating material removed completely, no damage to underlying substrate	None
	Selective Coatings Removal	3.1.2	Topcoat layer removed, no damage to underlying primer layer	None
	Strippable Area Assessment	3.1.3	At least 80% of surface area stripped	None
FLASHJET® Qualification Testing Program	High Cycle Fatigue Test	3.2	Varies by test	ASTM E466-96

3. TEST RESULTS

3.1 CH-53 Off-Aircraft Components Results

Seven CH-53 off-aircraft components were stripped using the FLASHJET® process at The Boeing Company's FLASHJET® Paint Stripping Cell in St. Louis, MO from February to March 1999. The seven components tested in this demonstration consisted of the cargo ramp, cargo door, auxiliary fuel tank, pylon, two personnel doors (upper and lower), and main rotor blade. The primary objective of this portion of the demonstration was to evaluate the effectiveness of the FLASHJET® process for removing the topcoat and leaving the underlying primer.

During the CH-53 off-aircraft component demonstration, the National Defense Center for Environmental Excellence (NDCEE) acted as an independent evaluator and recorded test results and observations for the testing activities. The NDCEE prepared a detailed results package which can be found in Appendix A of this Joint Test Report.

In accordance with Section 3.1.1 of the JTP, all stripped sections were visually inspected to determine if the FLASHJET® process caused any physical damage to the substrates. All seven off-aircraft components were visually inspected and no damage to the stripped substrates was found.

In accordance with Section 3.1.2 of the JTP, all stripped sections were inspected to determine if the FLASHJET® process stripped down to the primer. All sections were stripped down to the primer and passed this requirement.

In accordance with Section 3.1.3 of the JTP, to meet the minimal acceptance criteria requirement at least 80% of the external surface area would need to be stripped. The following table provides the visual depaint results for the CH-53 off-aircraft component testing.

Table 2: Visual Results for CH-53 Off-Aircraft Component Testing

Test Part	Visual Depaint Results (%)
Cargo Ramp	98
Cargo Door	98
Auxiliary Fuel Tank	98
Pylon	90
Personnel Doors	95
Main Rotor Blade	91

All of the CH-53 off-aircraft components passed the three effectiveness testing requirements.

3.2 SH-60 Seahawk Results

The SH-60 Seahawk demonstration was conducted at The Boeing Company's FLASHJET® Apache Paint Stripping Facility in Mesa, AZ from October to December 1999. The age of the aircraft was approximately fifteen years old at the time of the demonstration and there was no known record of the last full paint/depaint cycle for this aircraft. The color of the aircraft was a light faded gray.

The Naval Air Systems Command received a one-time approval to depaint a fleet SH-60 Seahawk from the PMA-299 (SH-60 Seahawk Program Manager) after the completion of Phase Ib of the FLASHJET® Qualification Testing Program. Results of the testing program showed that after a one-time depaint using the FLASHJET® process, the process does not cause any physical damage to the thin Aluminum substrates commonly found on the SH-60 Seahawk. However the input voltage parameters used in the stripping of the fatigue test specimens were not the maximum values often used in normal FLASHJET® stripping operations. For this reason the Naval Air Systems Command required that input parameters used in the stripping of the test specimens be used when stripping the SH-60 Seahawk. Those input parameters were as follows:

- Input Voltage – Not to exceed 2050 volts
- Flash Frequency – 4 Hz (May not exceed 1 flash per quarter inch of travel)
- Head Speed – 1 inch/second
- Standoff Distance – 2.185 ± 0.05 inch
- Substrate Angle – 21 ± 5 degrees
- All composite surfaces must be masked
- Strip paint from only the aluminum substrates with minimum thickness of 0.025"
- Leave 80% of primer intact

It should be noted that the maximum input voltage for the FLASHJET® process is 2300 volts. Stripping at 2050 volts requires more passes to remove the topcoat.

Before the aircraft was stripped the rotor blades, cowlings, and other protrusions were taken off the aircraft to maximize the stripping area for the demonstration. Random coating thickness measurements were taken on the aircraft. Fifty-three program/strip paths were used to depaint 60% of the aircraft. Appendix B contains all of the pertinent data from each of the fifty-three program/scan paths.

In accordance with Section 3.1.1 of the JTP, all sections of the SH-60 were visually inspected for possible substrate damage caused by the FLASHJET® process. One section of the aircraft was found to have substrate damage potentially caused by excessive heat buildup. On the back of the panel there was "bondo" like material which possibly caused the panel to heat up. Fortunately this panel was not flight critical and was replaced. After the panel was replaced, another aircraft inspection was conducted and no further damage was found.

In accordance with Section 3.1.2 of the JTP, all sections were visually inspected to determine if the FLASHJET® process removed only the topcoat. Each stripped section was inspected and the primer was visible thus passing this test requirement.

In accordance with Section 3.1.3 of the JTP, at least 80% of the external surface area needed to be stripped using the FLASHJET® process. Because of the limitations set by the Naval Air

Systems Command, only approximately 60% of the aircraft could be stripped using the FLASHJET® process. This portion of the test only covered the 60% of the aircraft that could be stripped using the FLASHJET® process. Each of the fifty-three scan/strip paths far exceeded the 80% surface area test. It was estimated that greater than 98% of the allowable external surface area was stripped using the FLASHJET® process. Only minimal hand sanding was required in certain areas that were not stripped.

3.3 FLASHJET® Qualification Testing Program Results

The purpose of the FLASHJET® Qualification Testing Program was to determine potential fatigue failures on thin Aluminum substrates possibly caused by the FLASHJET® process for rotary wing aircraft. In the Strategic Environmental Research and Development Program FLASHJET® project, a series of high cycle fatigue testing programs were conducted to determine potential fatigue failures for fixed wing aircraft. Results of these programs showed that the FLASHJET® process does not cause fatigue failures for fixed wing aircraft. The objective of this additional set of these high cycle fatigue programs was to qualify the FLASHJET® process on rotary wing aircraft where the Aluminum substrates are normally thinner than on fixed wing aircraft.

Four separate testing phases were conducted in this FLASHJET® Qualification Testing Program. Each phase focused on qualifying the FLASHJET® process on service specific items. The following testing phases were conducted to qualify the FLASHJET® process on rotary wing equipment:

- Phase Ia – SH-60 one-time FLASHJET® qualification on 0.100" drilled hole in 0.016" thick 2024-T3 and 7075-T6 specimens. One paint/depaint cycle. Test specimens drilled after paint/depaint cycle.
- Phase Ib – SH-60 one-time FLASHJET® qualification on 0.100" drilled hole in 0.025" thick 7075-T6 specimens. One paint/depaint cycle. Test specimens drilled after paint/depaint cycle.
- Phase Ic – Testing to support AVRDEC Requirements on 2024-T3 and 7075-T6 center hole and center crack specimens at 0.025" thickness. Test specimens drilled or cracked before paint/depaint cycle(s). One or five paint/depaint cycles, depending on the test requirement.
- Phase II – Testing to qualify the life cycle use of the FLASHJET® process on 0.025" thick 2024-T3 and 7075-T6 specimens. Five paint/depaint cycles. Test specimens drilled before paint/depaint cycle.

Three types of conditions were used in the FLASHJET® Qualification Testing Program. These conditions are as follows:

- Condition A: control panel, conversion coat, no paint, no strip
- Condition B: strip to saturate (3 passes or until coating is removed plus three additional passes)
- Condition C: strip to substrate and repaint 5 times

All panels were solvent cleaned and chromate conversion coated per MIL-C-5541. Test Conditions B and C were primed using MIL-PRF-85582 and then painted using MIL-PRF-85285.

3.3.1 Phase Ia Results

Phase Ia of the FLASHJET® Qualification Testing Program was conducted at the Patuxent River Naval Air Station, MD from August to November 1998. Panels consisted of both 2024-T3 and 7075-T6, 0.016” Aluminum material. All panels, except for the control panels that were conversion coated, were pretreated, primed, and painted. Test specimens undergoing FLASHJET® stripping were “stripped to saturate.” The “strip to saturate” condition simulates the worst case scenario where the FLASHJET® process would continue operating even when all of the coating has been removed.

Tables 3 and 4 on the following two pages provide the results for the 7075-T6 Phase Ia testing program.

Table 3: Phase Ia – 7075-T6, 0.016”, R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	40	7,228		8,310	
		6,728		7,993	
		8,280		8,198	
		7,103	7,335	10,145	8,662
0.1	22	50,210		94,163	
		89,234		289,105	
		416,481		67,967	
		81,404	159,332	1,450,033	475,317
0.1	20	1,578,351		10,433,404 (run out)	
		240,884		13,535,414 (run out)	
		83,179		106,733	
		10,402,266 (run out)	3,076,170	122,990	6,049,635

$R = \Phi_{min}/\Phi_{max}$

N_f = Failure Point

ksi = kilopounds per square inch

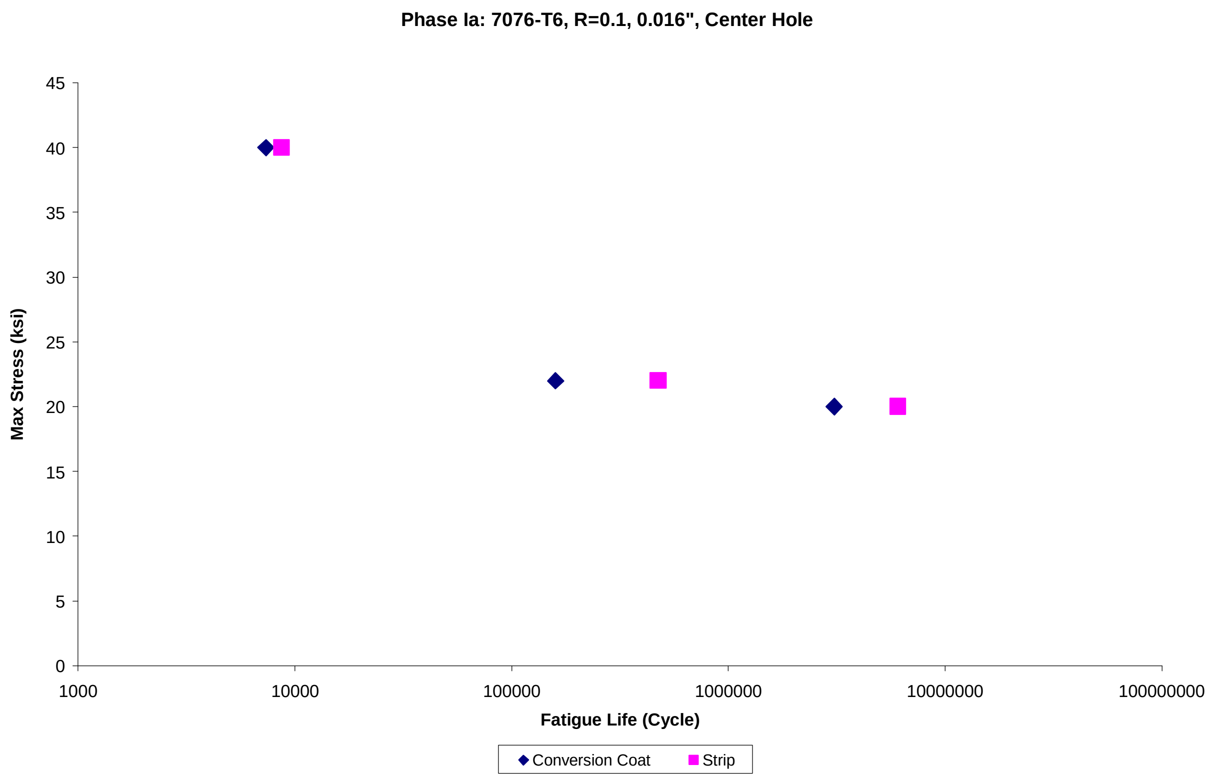


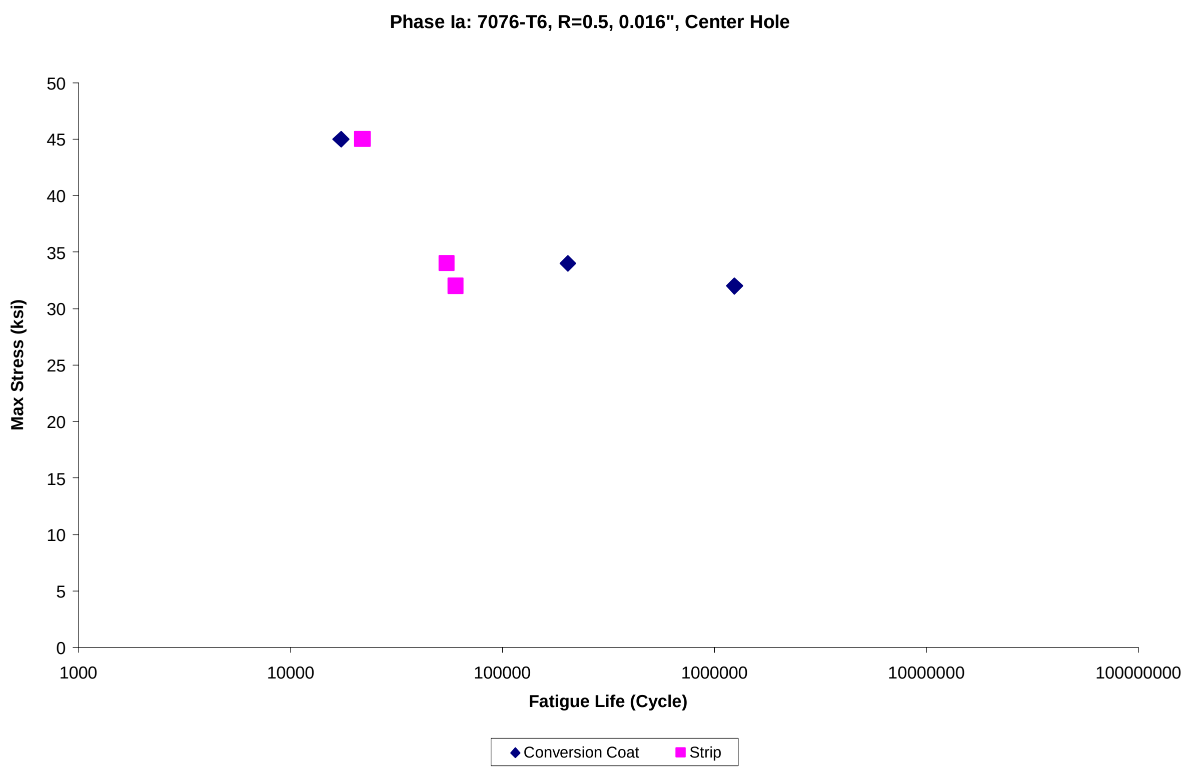
Table 4: Phase Ia – 7075-T6, 0.016”, R=0.5, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.5	45	17,341		19,336	
		18,296		20,643	
		17,142		22,511	
		16,536	17,329	25,176	21,917
0.5	34	49,692		77,304	
		42,368		53,926	
		89,732		44,047	
		633,811	203,901	43,669	54,737
0.5	32	1,255,165		56,767	
		1,045,592		71,237	
		308,950		59,922	
		2,366,906	1,244,153	52,814	60,185

$R = \Phi_{min}/\Phi_{max}$

N_f = Failure Point

ksi = kilopounds per square inch



The two charts on the previous pages compare the conversion coated specimens to the specimens stripped with the FLASHJET® process. The first chart compares the R=0.1 stress ratio for both the conversion coated and FLASHJET® specimens. Analysis of this chart shows that at a stress ratio of 0.1, the FLASHJET® process does not cause any damage to the substrate at this stress ratio. The second chart compares the R=0.5 stress ratio. Analyzing this chart shows that the FLASHJET® process could potentially cause damage to the 0.016", 7075-T6 substrate. For this reason the Naval Air Systems Command temporarily put a hold on the SH-60 Seahawk demonstration until further testing was conducted. Phase Ib of the FLASHJET® Qualification Testing Program was established by the Naval Air Systems Command to further qualify the SH-60 Seahawk for a one-time depaint using the FLASHJET® process.

The Boeing Company's Failure Analysis Laboratory further analyzed the fatigue specimens to determine the potential causes of the fatigue failures. Upon further review The Boeing Company's Failure Analysis Laboratory determined the following:

- "Early initiation of FLASHJET® fatigue specimens appears to be associated with significantly rougher surface preparation."
- " No indication of thermal damage to the fatigue test specimens was evident from hardness and conductivity testing."

Tables 5 and 6 on the following two pages provide the results for the 2024-T3 Phase Ia testing program.

Table 5: Phase Ia – 2024-T3, 0.016", R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	30	43,826		33,315	
		54,401		39,952	
		36,322		28,405	
		40,546	43,774	54,064	38,934
0.1	25	113,727		162,204	
		89,046		146,552	
		85,361		70,504	
		128,990	104,281	273,105	163,091
0.1	22	6,212,885		8,112,489	
		270,699		6,868,266	
		6,550,402		140,741	
		6,711,942	4,936,482	8,143,659	5,816,289

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

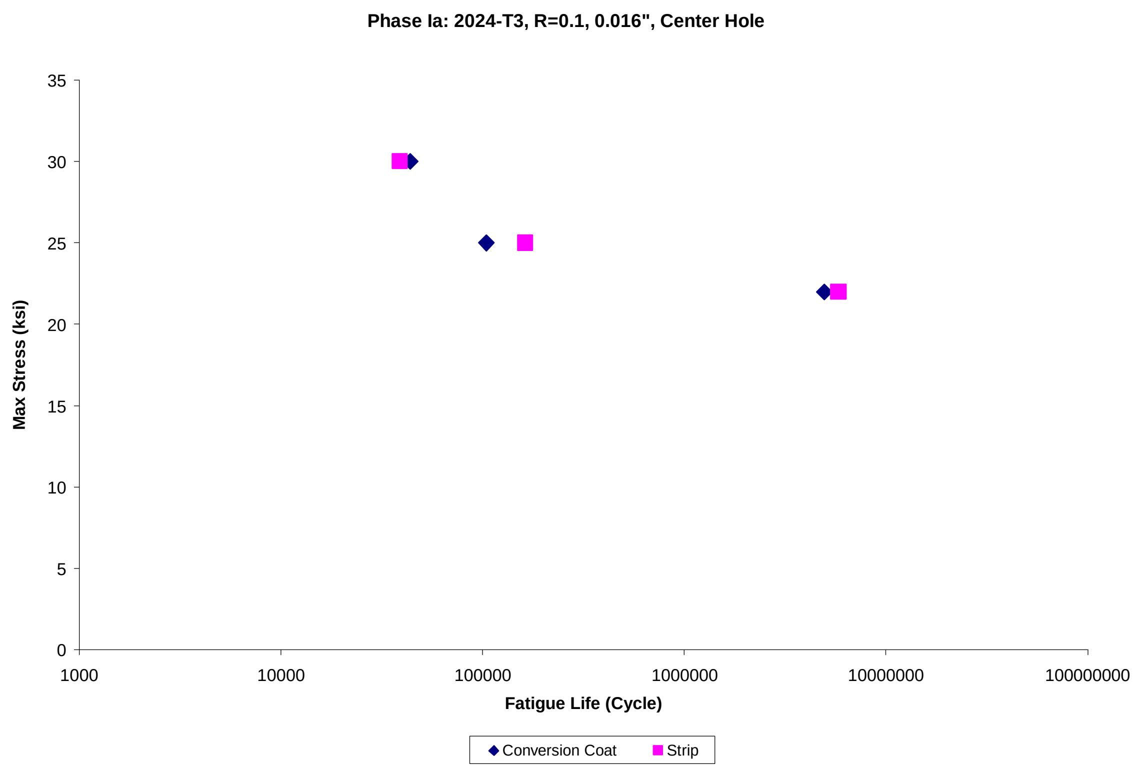
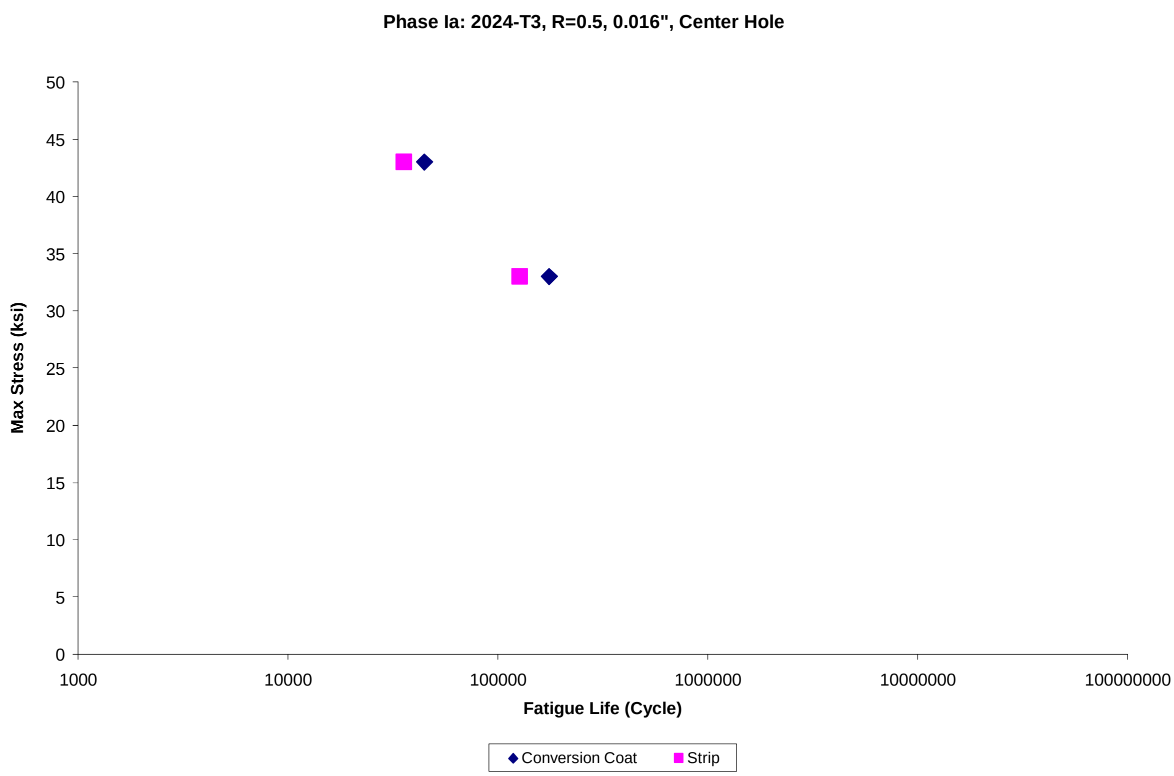


Table 6: Phase Ia – 2024-T3, 0.016", R=0.5, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.5	43	48,829		37,098	
		35,877		38,385	
		46,325		33,890	
		47,143	44,544	33,298	35,668
0.5	33	148,880		98,784	
		193,996		178,018	
		139,066		97,483	
		218,970	175,228	134,907	127,298

R = Φ_{min}/Φ_{max}
N_f = Failure Point
ksi = kilopounds per square inch



The preceding charts show that the FLASHJET® process does not have any effect on 0.016", 2024-T3 Aluminum for a one-time depaint. However, since the SH-60 Seahawk is mainly composed of 7076-T6 Aluminum, these results were not adequate to grant a one-time depaint approval using the FLASHJET® process and additional testing was required.

3.3.2 Phase Ib Results

Phase Ib of the FLASHJET® Qualification Testing Program was conducted at the Patuxent River Naval Air Station, MD from April to June 1999. This testing focused on qualifying the FLASHJET® process for a one-time depaint using a fleet SH-60 Seahawk. In this phase only 7075-T6, 0.025" Aluminum was used to determine potential fatigue failure caused by the FLASHJET® process.

Table 7 provides the results for the Phase Ib 7075-T6, 0.025", R=0.1 testing program. Table 8 provides the results for the Phase Ib 7075-T6, 0.025", R=0.5 testing program.

Table 7: Phase Ib – 7075-T6, 0.025", R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	40	5,325 6,391 5,630 5,430	5,694	5,476 6,547 5,966 6,963	6,238
0.1	30	13,796 21,329 33,180 21,908	22,553	12,778 16,570 16,765 21,457	16,893
0.1	25	30,555 34,953 45,309 41,994	38,203	32,246 40,707 22,039 46,323	35,329
0.1	20	68,932 72,758 75,350 65,993	70,758	64,579 89,256 113,014 100,299	91,787
0.1	15	193,121 146,944 263,427 223,672	206,791	261,522 227,641 200,673 351,792	260,407

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

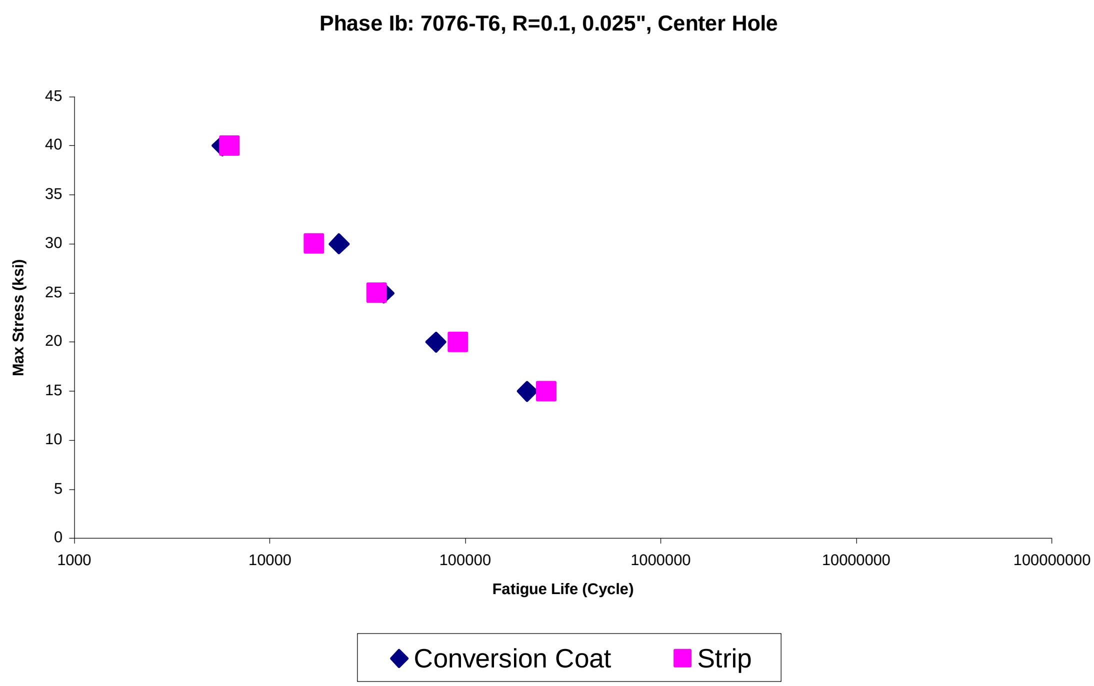


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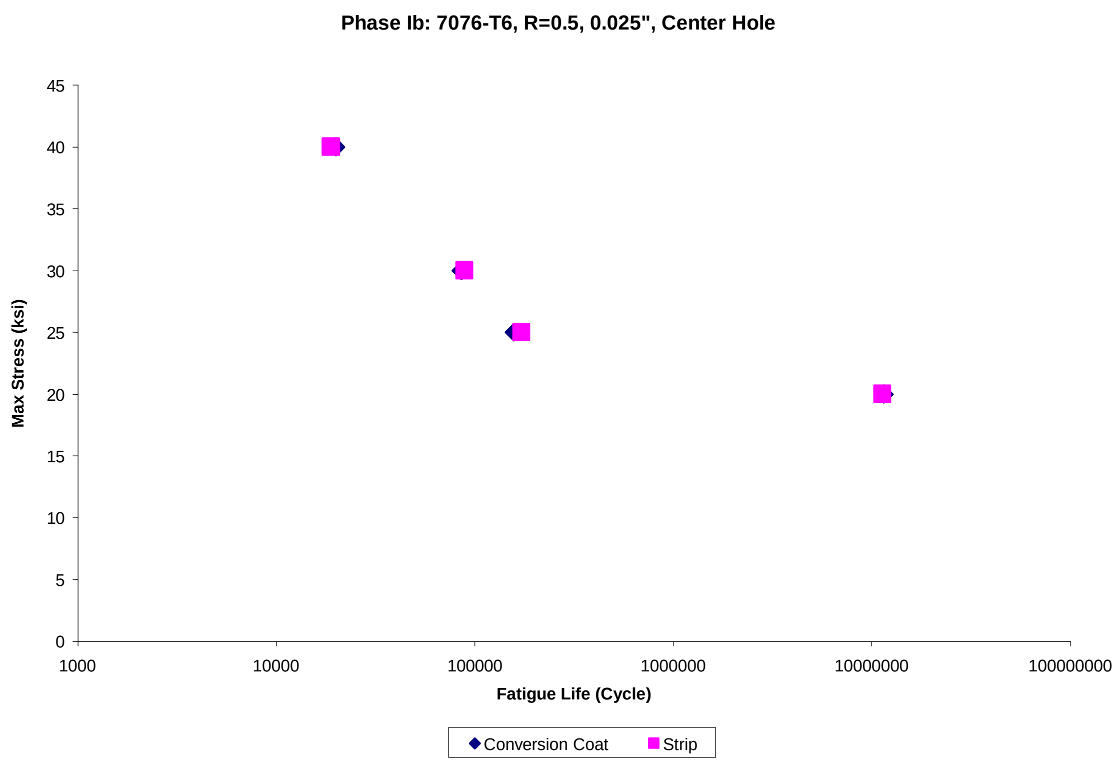
Table 8: Phase Ib – 7075-T6, 0.025", R=0.5, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.5	40	16,613		18,779	
		17,726		18,702	
		22,937		20,079	
		22,603	19,970	17,994	18,889
0.5	30	88,235		68,495	
		80,854		92,878	
		82,275		95,387	
		90,175	85,385	98,097	88,714
0.5	25	158,694		173,845	
		137,117		178,776	
		126,182		154,639	
		205,576	156,892	180,926	172,047
0.5	20	10,337,830		10,175,773	
		9,040,745		13,771,430	
		10,582,849		10,414,478	
		16,041,717	11,500,785	10,796,202	11,289,471

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch



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The preceding charts show the plots of both the R=0.1 and R=0.5 show no potential fatigue damage caused by the FLASHJET® process. With these favorable results, the PMA-299 (SH-60 NAVAIR Program Manager) gave permission to the Naval Air Systems Command for a one-time strip approval of one SH-60 Seahawk for this demonstration.

3.3.3 Phase Ic Results

Phase Ic of the FLASHJET® Qualification Testing Program was conducted at the U.S. Army Research Laboratory, Aberdeen Proving Ground, MD from May 2000 to April 2001. This testing focused on qualifying the FLASHJET® process for all Army rotary wing Aluminum aircraft. Structural engineers from the U.S. Army Aviation Research Development and Engineering Center (AVRDEC) requested a different specimen preparation method which they felt better simulated real time conditions. Specifically, AVRDEC requested that all machined holes and cracks on the test specimens be prepared prior to the paint/depaint cycles instead of after the paint/depaint cycles have occurred.

In this phase both 2024-T3 and 7075-T6, 0.025" Aluminum specimens were used in this portion of the program to determine potential fatigue failure caused by the FLASHJET® process. The following tables show the results for the center hole specimens for all of Phase Ic:

- Table 9: 2024-T3, 0.025", R=0.1, test conditions A and B
- Table 10: 7075-T6, 0.025", R=0.1, test conditions A and B
- Table 11: 2024-T3, 0.025", R=0.1, test conditions A and C
- Table 12: 7075-T6, 0.025", R=0.1, test conditions A and C

The following tables show the results for the center crack initiated specimens:

- Table 13: 2024-T3, 0.025", R=0.1, test conditions A and B
- Table 14: 7075-T6, 0.025", R=0.1, test conditions A and B
- Table 15: 2024-T3, 0.025", R=0.1, test conditions A and C
- Table 16: 7075-T6, 0.025", R=0.1, test conditions A and C

A graph of the maximum stress (ksi) to the fatigue life (cycle) will follow each table.

Table 9: Phase Ic – center hole, 2024-T3, 0.025", R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	13	274,902		170,497	
		198,971		185,310	
		232,320		189,909	
		203,259		198,904	
		221,814		223,794	
		162,743	215,668	228,047	199,410
0.1	10.5	641,991		545,017	
		309,896		596,898	
		498,805		766,899	
		333,433		1,697,339	
		352,652		2,258,006	
		371,038	417,969	3,000,000	1,477,359

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

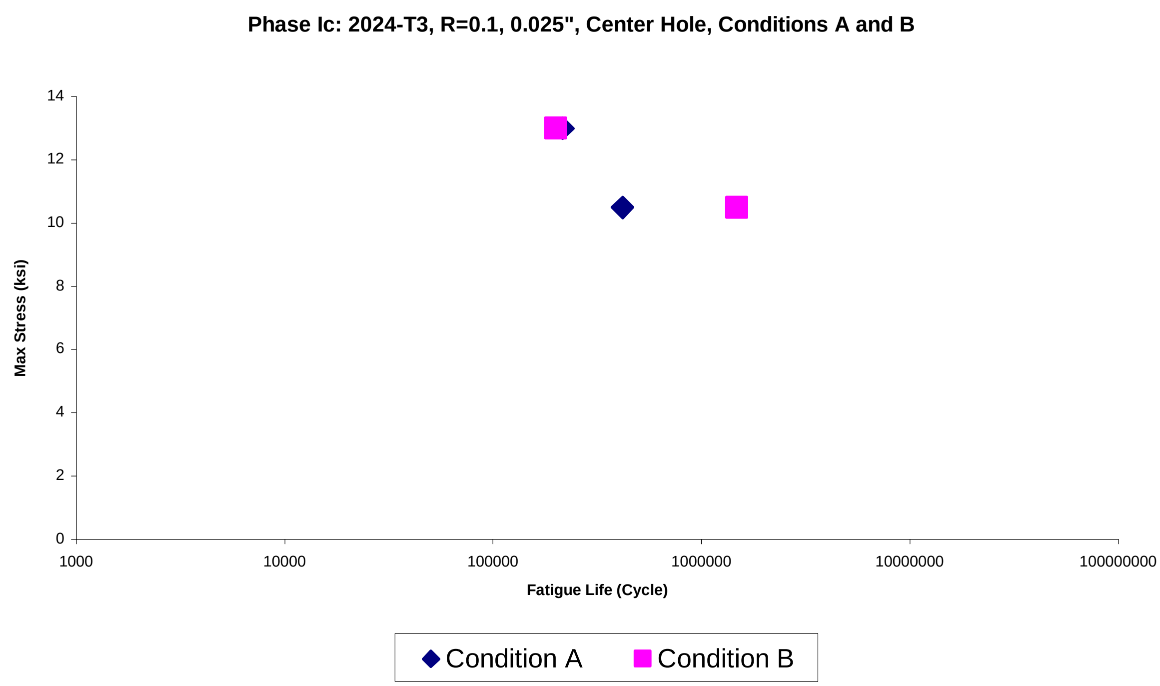

Table 10: Phase Ic – center hole, 7075-T6, 0.025", R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	12.5	105,162		295,616	
		117,846		299,857	
		122,124		194,387	
		104,994		325,364	
		103,964		141,152	
		126,666	113,459	252,939	251,553
0.1	10	411,210		2,026,900	
		365,178		3,000,000	
		505,506		287,679	
		304,025		3,000,000	
		261,593		3,000,000	
		309,010	359,420	1,208,557	2,087,189

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

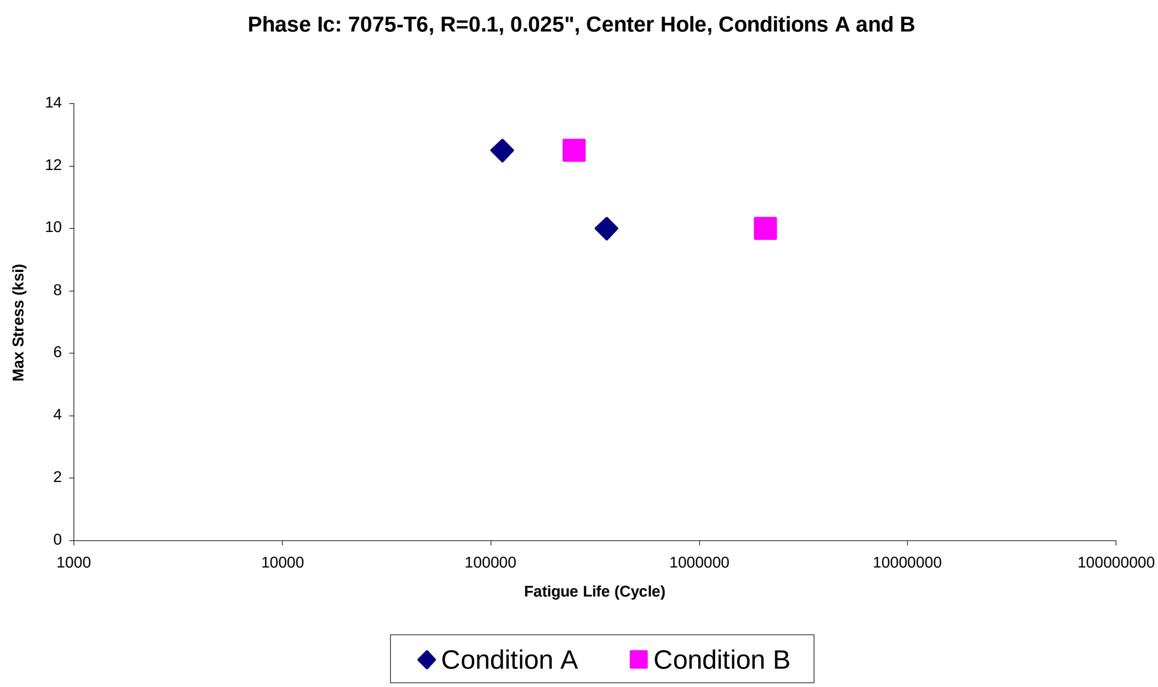

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Table 11: Phase Ic – center hole, 2024-T3, 0.025", R=0.1, test conditions A and C

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
0.1	13.0	274,902		329,144	
		198,971		301,420	
		232,320		314,272	
		203,259		487,852	
		221,814		781,168	442,771
		162,743	215,668		
0.1	10.5	641,991		709,079	
		309,896		507,457	
		498,805		618,973	
		333,433		645,506	
		352,652		654,538	627,111
		371,038	417,969		

NOTE: Condition C specimens were supposed to be run at the maximum stress of 13.0 ksi however were run at 12.5 ksi due to an error in the setup of the fatigue testing machine. According to the Army Research Laboratory, this is not a major cause for concern.
$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

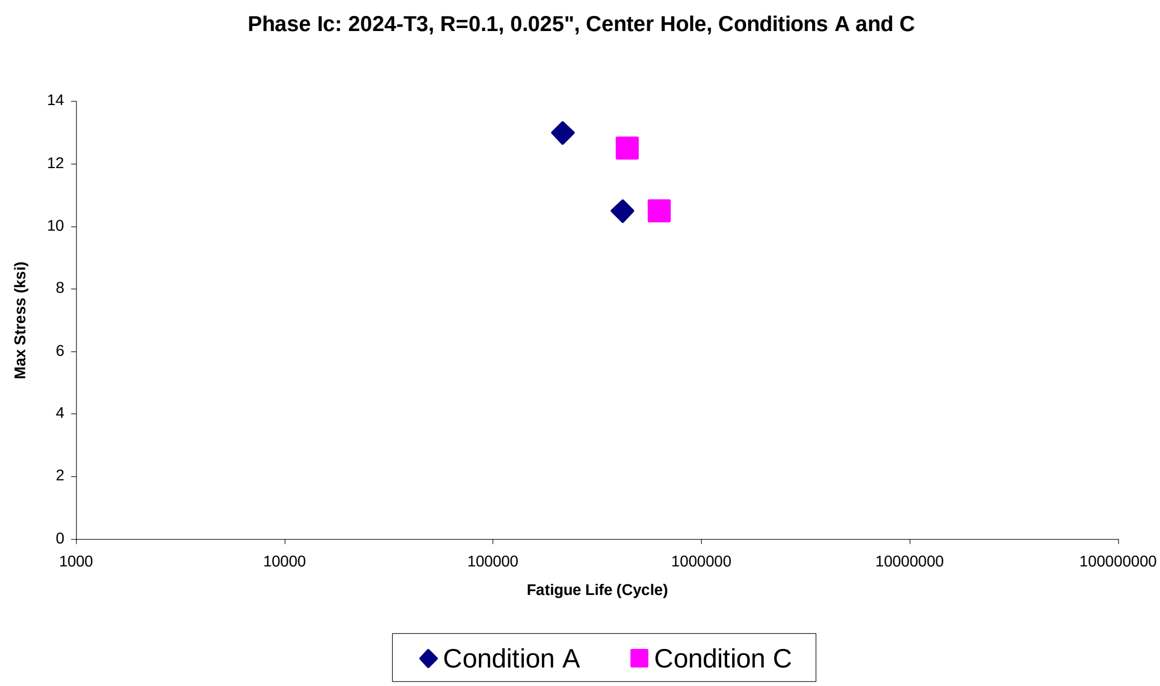
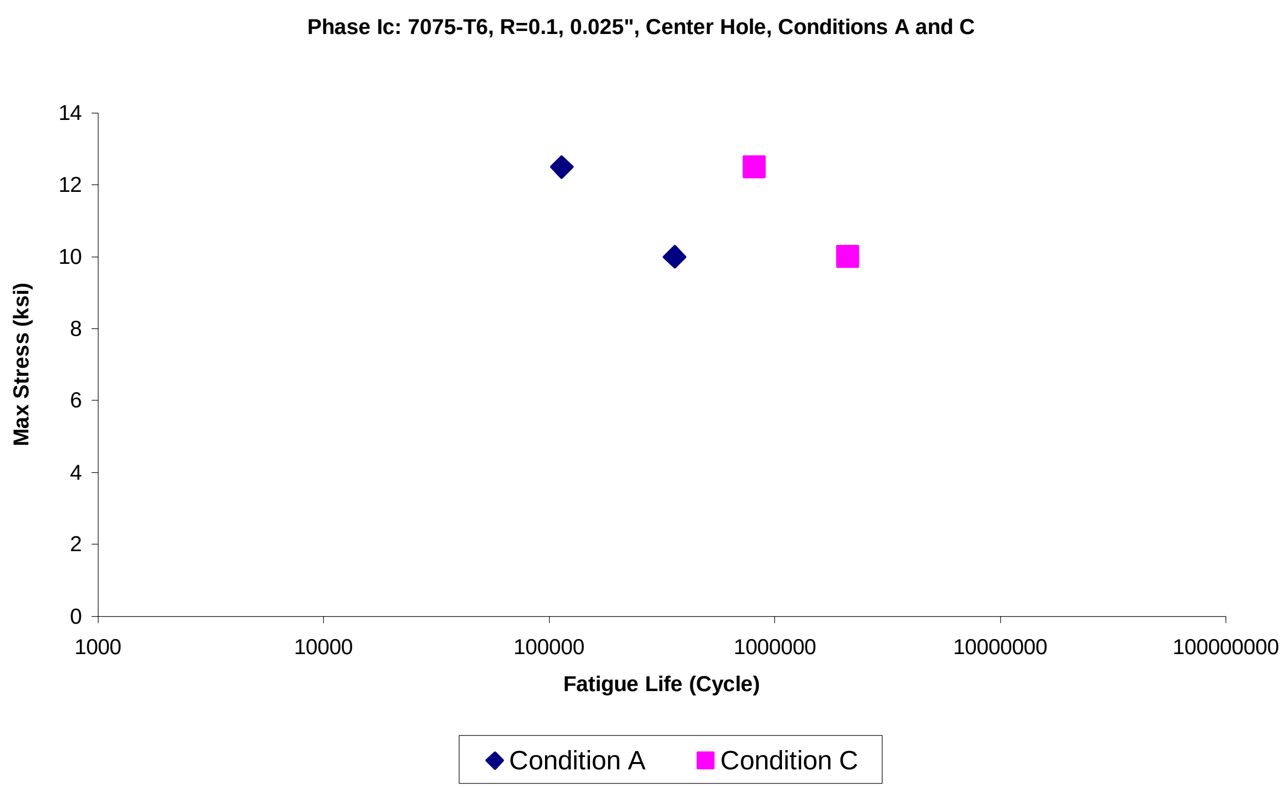


Table 12: Phase Ic – center hole, 7075-T6, 0.025", R=0.1, test conditions A and C

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
0.1	12.5	105,162		135,794	
		117,846		79,998	
		112,124		916,968	
		104,994		291,277	
		103,964		442,206	
		126,666	113,459	3,000,000	811,041
0.1	10	411,210		1,016,300	
		365,178		3,000,000	
		505,506		3,000,000	
		304,025		2,230,245	
		261,593		1,299,597	2,109,228
		309,010	359,420		

R = Φ_{min}/Φ_{max}
N_f = Failure Point
ksi = kilopounds per square inch

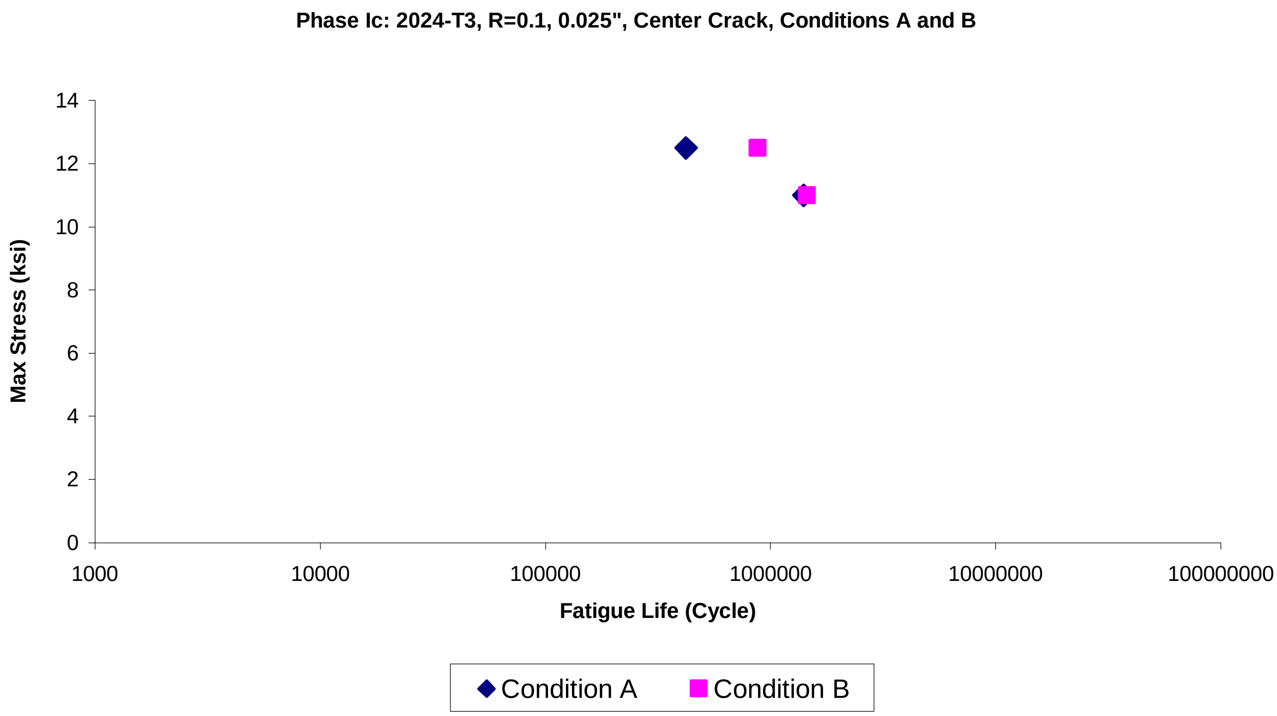


FINAL

Table 13: Phase Ic – center crack, 2024-T3, 0.025", R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	12.5	445,632		594,181	
		403,531		1,370,264	
		425,312		1,025,740	
		352,549		521,426	877,903
		468,004			
		430,457	420,914		
0.1	11	618,761		3,000,000	
		3,000,000		727,500	
		550,059		1,208,382	
		1,041,699		1,643,358	
		3,000,000		532,656	
		766,018		2,227,188	
		486,011	1,403,221	844,952	1,454,862

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch



FINAL

Table 14: Phase Ic – center crack, 7075-T6, 0.025”, R=0.1, test conditions A and B

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition B N_f (cycle)	Condition B Ave N_f (cycle)
0.1	11	289,419		318,627	
		244,362		265,547	
		236,917		260,759	
		257,594		334,810	
		234,324		279,402	
		255,181		242,256	
		255,861	253,380	228,643	275,721
0.1	10	315,250		523,606	
		299,152		213,872	
		280,842		362,251	366,576
		266,105			
		509,036	334,077		

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

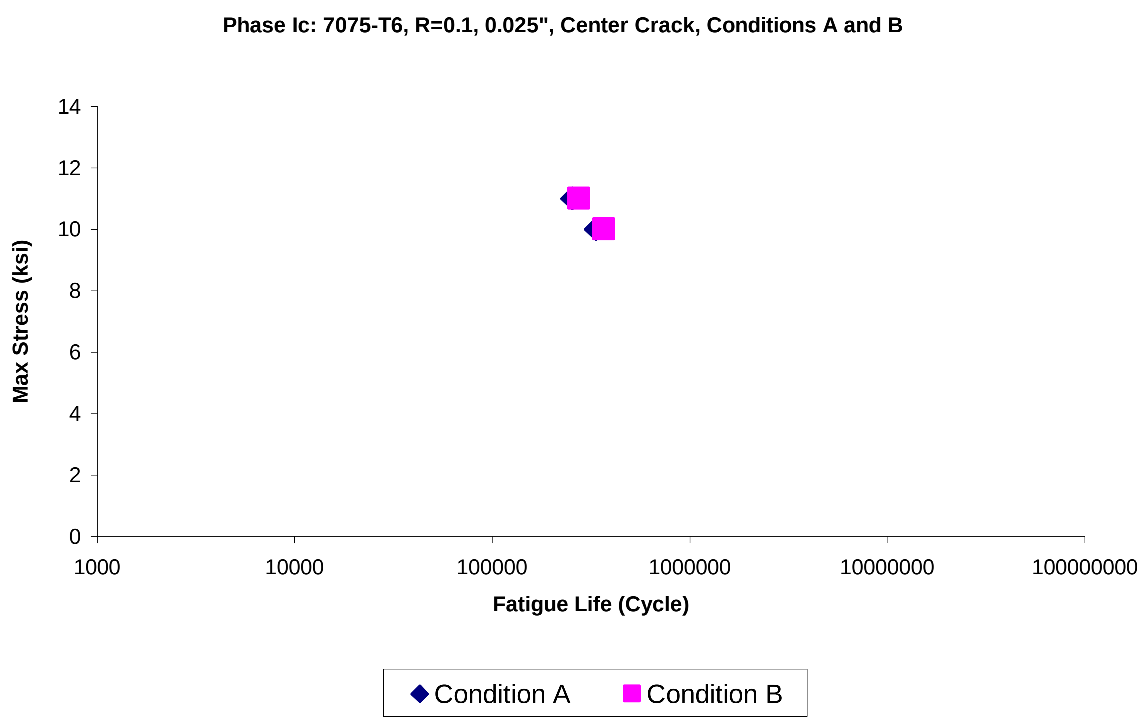


Table 15: Phase Ic – center crack, 2024-T3, 0.025", R=0.1, test conditions A and C

R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
0.1	12.5	445,632		560,936	
		403,531		380,365	
		425,312		453,181	
		352,549		392,754	
		468,004		374,575	432,362
		430,457	420,914		
0.1	11	618,761		251,832	
		3,000,000		3,000,000	
		550,059		938,662	
		1,041,699		874,870	1,267,916
		3,000,000			
		766,018			
		486,011	1,403,221		

$R = \Phi_{min}/\Phi_{max}$

N_f = Failure Point

ksi = kilopounds per square inch

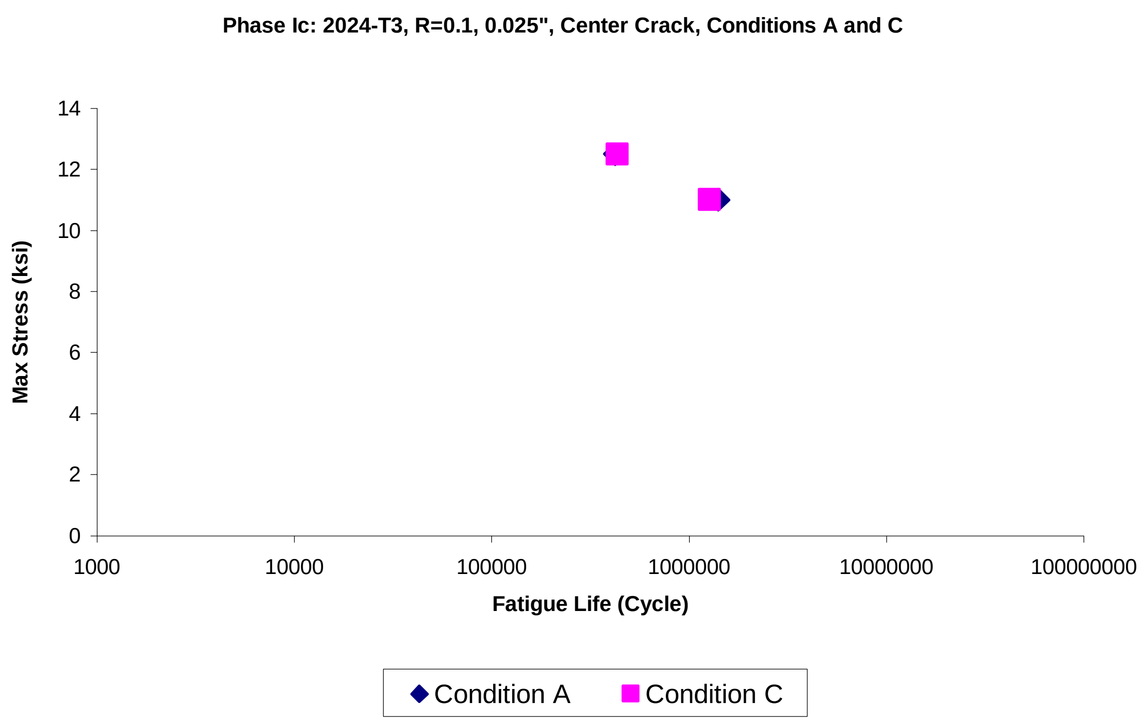


Table 16: Phase Ic – center crack, 7075-T6, 0.025", R=0.1, test conditions A and C

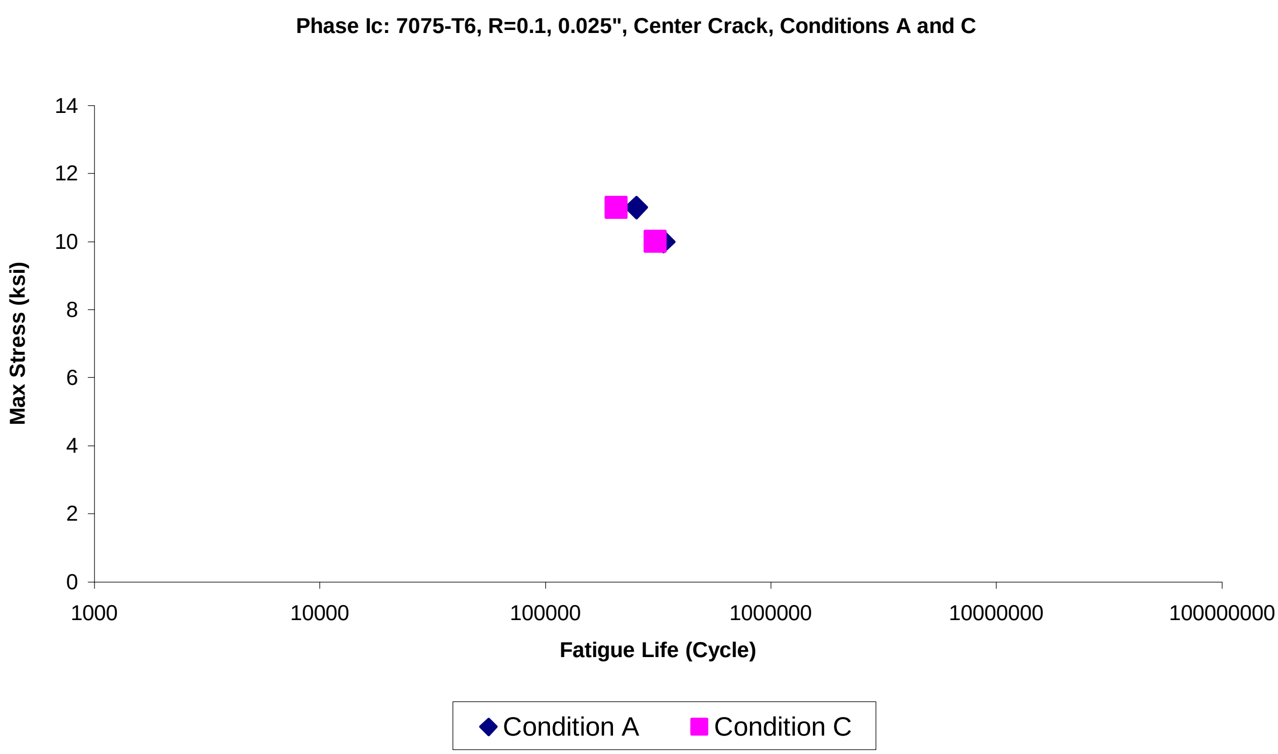
R	Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
0.1	11	289,419		238,154	
		244,362		175,004	206,579
		236,917			
		257,594			
		234,324			
		255,181			
		255,861	255,380		
0.1	10	315,250		308,338	308,338
		299,152			
		280,842			
		266,105			
		509,036	334,077		

NOTE: A large portion of the specimens set aside for 7075-T6, Condition C, Center Crack were run at the wrong stress level. Only the data for the correct stress level was used for presenting the results.

$R = \Phi_{min}/\Phi_{max}$

N_f = Failure Point

ksi = kilopounds per square inch



The Army Research Laboratory has thoroughly reviewed the fatigue testing data and does not have any major concerns with the final results of this fatigue testing program. Throughout the evaluation period, many Army Research Laboratory scientists noted how the fatigue life of specimens stripped via the FLASHJET® process actually increased the strength of the specimens as it was originally assumed that the process would decrease the life of the specimens.

Currently the U.S. Army Aviation and Missile Command has given interim approval to depaint metallic substrates pending the final results of this FLASHJET® Qualification Testing Program. The Army Research Laboratory has presented the results to the AVRDEC and full approval of the FLASHJET® process is expected from AVRDEC for all Army rotary wing metallic substrates by the end of 2001.

3.3.4 Phase II Results

Phase II of the FLASHJET® Qualification Testing Program was conducted at the Patuxent River Naval Air Station, MD from June to September 2000. The objective of this phase was to support the qualification of the FLASHJET® process for life cycle paint stripping of fatigue critical helicopter airframe structure. This test program addressed the high cycle fatigue behavior of 0.025" 7075-T6 and 2024-T3 Aluminum alloys after five paint/depaint cycles. All of the specimens were drilled with a 0.100" center hole before the paint/depaint cycles began.

The following tables show the results of the Phase II testing:

- Table 17: 2024-T3, 0.025", R=0.1, test conditions A and C
- Table 18: 2024-T3, 0.025", R=0.5, test conditions A and C
- Table 19: 7075-T6, 0.025", R=0.1, test conditions A and C
- Table 20: 7075-T6, 0.025", R=0.5, test conditions A and C

A graph of the maximum stress (ksi) to the fatigue life (cycle) will follow each table.

Table 17: Phase II – 2024-T3, 0.025”, R=0.1, test conditions A and C

Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
40	7,442		4,741	
	8,972		7,410	
	8,627		7,847	
	8,857	8,475	7,714	
			7,127	6,968
30	39,929		24,666	
	30,408		30,615	
	27,608		44,508	
	32,025	32,493	28,100	31,972
20	126,649		141,938	
	173,515		168,236	
	163,970		153,498	
	147,424	152,890	143,788	151,865
10	10,230,164		10,608,870	
	13,554,939		1,772,338	
	10,503,763		10,325,921	7,569,043
	10,332,741	11,155,402		

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

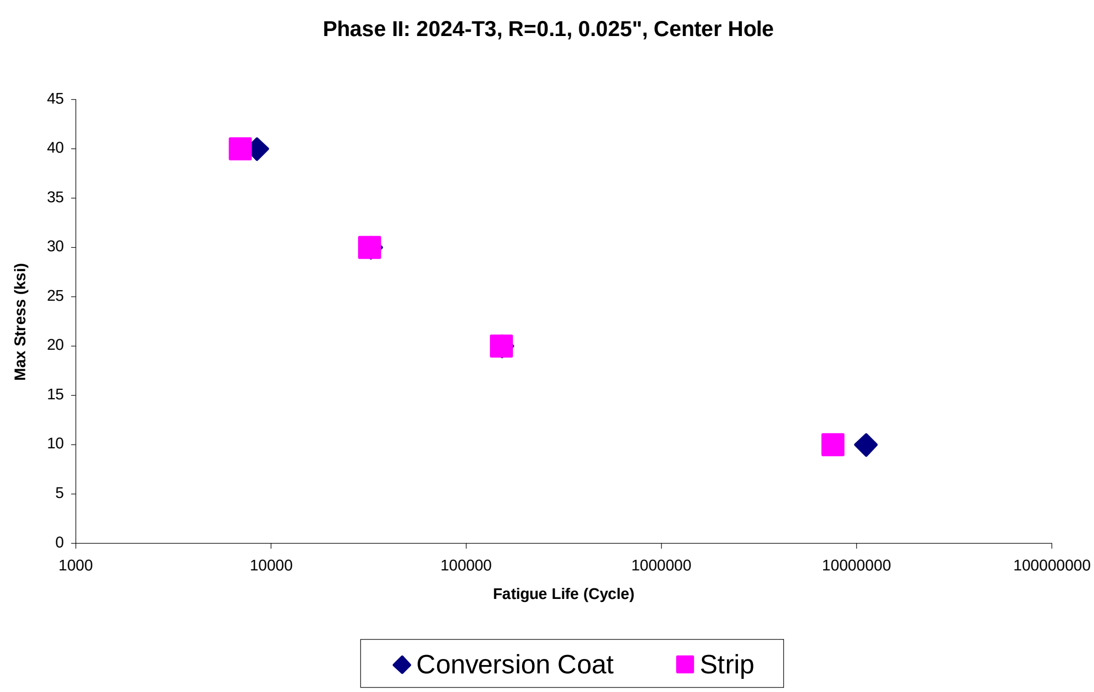


Table 18: Phase II – 2024-T3, 0.025”, R=0.5, test conditions A and C

Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
40	38,586		40,767	
	48,136		49,722	
	49,157		40,182	
	52,180	47,015	50,412	36,198
30	177,583		128,473	
	152,160		151,659	
	153,824		155,252	
	180,124		154,512	147,474
	146,237	161,986		
25	355,833		336,183	
	222,672		288,209	
	254,720		259,735	
	274,353	276,895	269,400	288,382
20	10,377,420		640,127	
	2,146,244		10,333,541	
	520,210		13,788,111	
	644,783	3,422,164	1,019,112	6,190,731

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

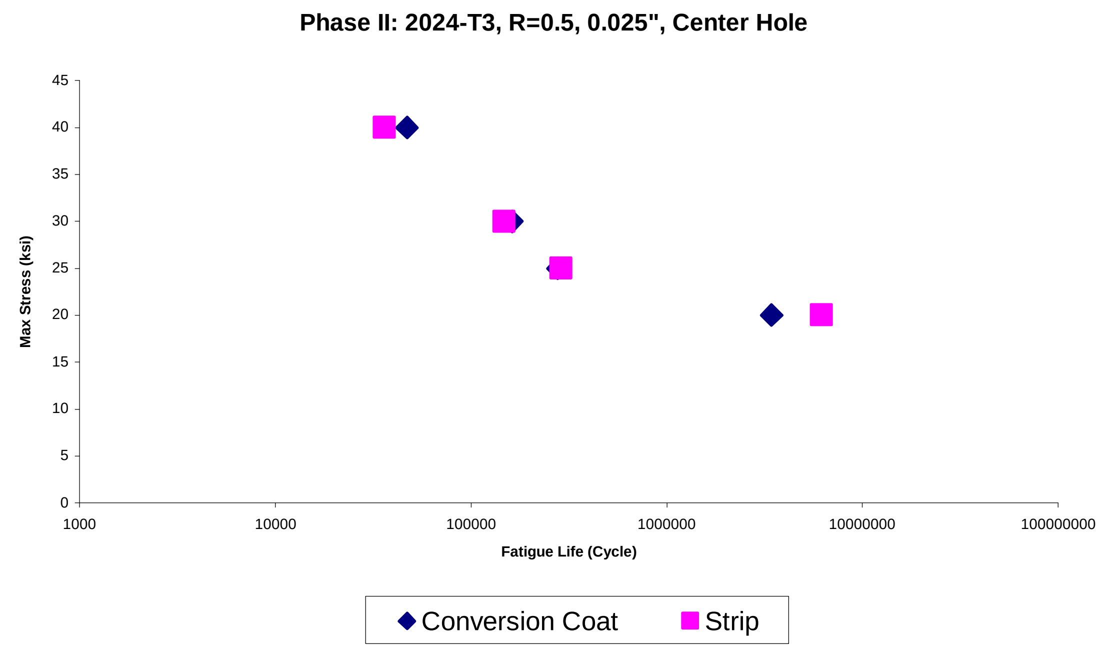


Table 19: Phase II – 7075-T6, 0.025", R=0.1, test conditions A and C

Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
40	5,474		7,093	
	4,746		6,938	
	5,885		7,231	
	5,737	5,461	6,068	6,833
30	20,614		17,811	
	19,573		20,000	
	20,639		18,134	
	22,254	20,770	23,727	19,918
20	91,787		82,389	
	78,845		116,427	
	78,900		79,536	
	73,585	80,779	110,634	97,247
10	12,418,411		13,449,139	
	13,777,141		10,205,523	
	10,349,908		13,818,446	
	14,177,322	12,680,696	10,268,125	11,935,308

$R = \Phi_{min}/\Phi_{max}$
N_f = Failure Point
ksi = kilopounds per square inch

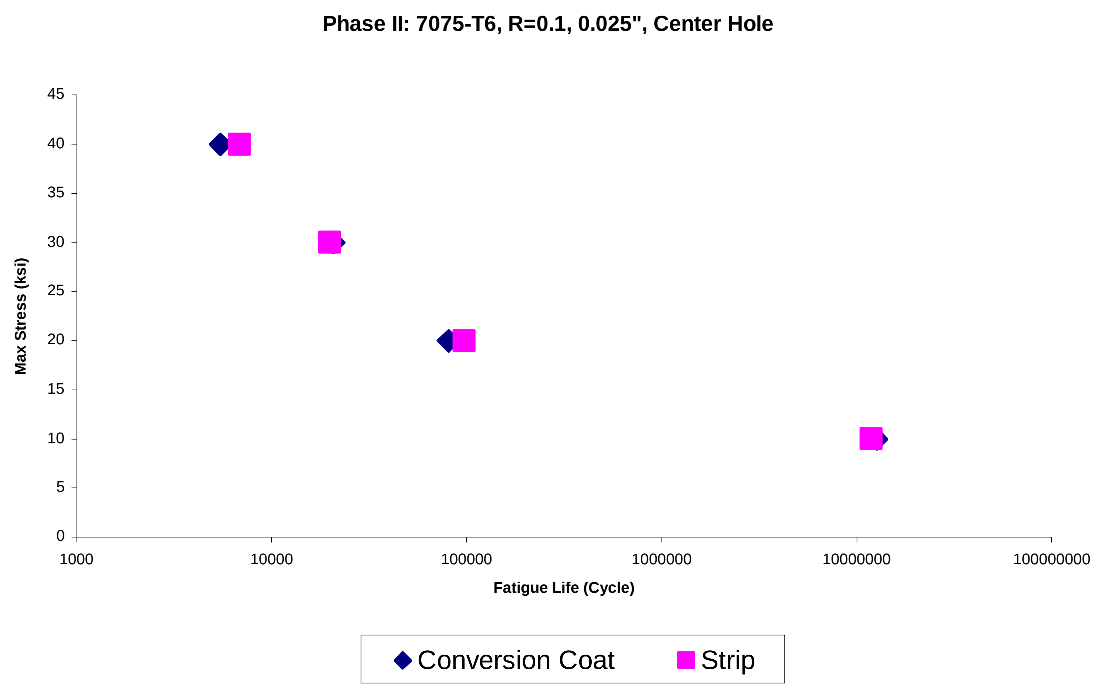


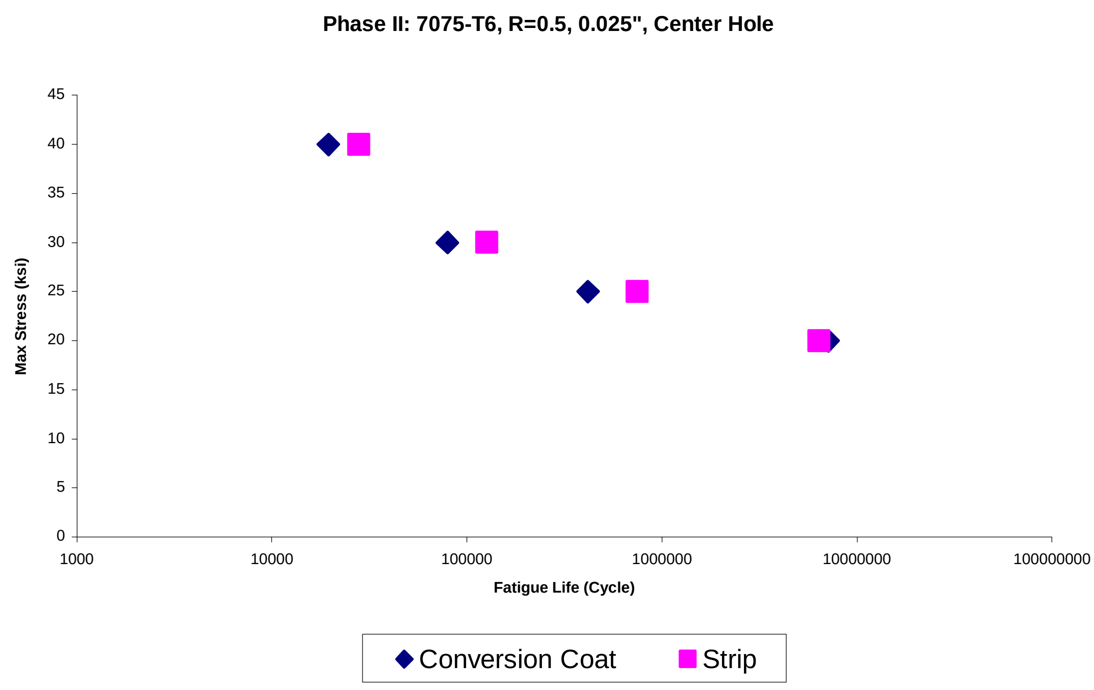
Table 20: Phase II – 7075-T6, 0.025", R=0.5, test conditions A and C

Max Stress (ksi)	Condition A N_f (cycle)	Condition A Ave N_f (cycle)	Condition C N_f (cycle)	Condition C Ave N_f (cycle)
40	18,455		32,660	
	18,298		23,788	
	21,068		48,204	
	20,141	19,491	34,916	27,914
30	72,765		144,862	
	68,147		111,668	
	123,308		153,653	
	53,287	79,377	96,696	126,720
25	164,504		184,414	
	1,227,813		2,844,216	
	128,257		262,047	
	149,307	417,470	243,930	
			204,830	747,887
20	10,199,918		17,190,968	
	187,901		1,453,952	
	10,986,714	7,124,844	539,214	6,394,711

$R = \Phi_{min}/\Phi_{max}$

N_f = Failure Point

ksi = kilopounds per square inch



Results of these fatigue testing scenarios show that the FLASHJET® does not affect 0.025" thin skin Aluminum 2024-T3 and 7075-T6 0.025" substrates. The Naval Air Systems Command is in the process of drafting up a process specification authorizing the use of the FLASHJET® process on rotary wing 0.025" 2024-T3 and 7075-T6 Aluminum substrates.

4. SUMMARY AND RECOMMENDATIONS

By implementing the FLASHJET® process at DoD installations, the DoD has the potential to drastically cut the amount hazardous chemicals and materials used in DoD painting operations. The FLASHJET® process uses no hazardous chemicals or materials in the depainting process and generates very little waste.

Results from this rotary wing demonstration/validation show that the FLASHJET® process is a viable alternative for DoD installations to implement over their traditional coating removal processes. Greater than 90% coating removal was seen during the CH-53 off-aircraft component demonstration and greater than 98% of the approved surface area topcoat of the SH-60 was removed without any significant problems. The results from the FLASHJET® Qualification Testing Program showed that the FLASHJET® process does not harm the thin Aluminum substrates commonly found on rotary wing aircraft. Material and structural engineers within the three participating services are drafting up process specifications to grant the approval of the FLASHJET® process on rotary wing aircraft at Aluminum thicknesses greater than 0.025".

All three services that participated in this project are drafting specifications granting the approval of the FLASHJET® process for rotary wing aircraft. The U.S. Navy and U.S. Air Force expect to have an approved specification by the summer of 2001. The U.S. Army has already given interim approval for using the FLASHJET® process on rotary wing aircraft via an AMCOM Engineering Directive (AED-A2049, 13 SEP 00) for external surfaces of Army aircraft. At present, the Corpus Christi Army Depot, TX is using the FLASHJET® process on all types of Army aircraft and plan to use the process also on Navy and Air Force equipment.

CH-53 Off-Aircraft Components Data Sheets

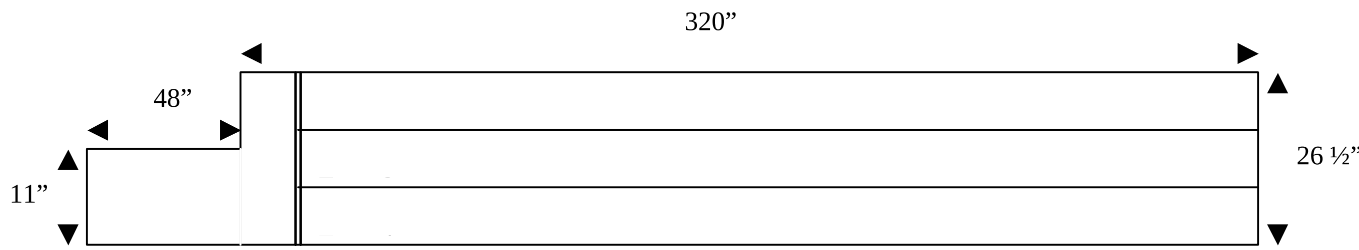
The following pages show the results of the CH-53 off-aircraft component demonstration in St. Louis, MO in accordance with parameters set in the Joint Test Protocol.

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*2 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*CH-53 Main Rotor Blade*

<u>Test Setup</u>

(Designate scan paths by hand on sketch below)



<u>Pre-test check</u>

Coating Thickness Survey

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*3.8*	*5.3*	*5.6*	*4.1*	*5.5*	*4.5*	*2.8*	*2.1*	*3.7*	*2.9*	*4.03*
Zone 2	*3.2*	*2.3*	*3.7*	*5.0*	*4.9*	*3.6*	*6.5*	*4.5*	*3.1*	*2.2*	*3.90*
Zone 3	*3.4*	*3.1*	*3.4*	*5.8*	*6.3*	*3.9*	*7.4*	*6.6*	*3.4*	*3.3*	*4.66*
Zone 4											
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

*Thickness measured every 2-½ feet of the blade length.

Test Data

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)	*8480*	*8480*	*8480*								
% Stripped (visual)	*90, final*	*85, final*	*85, final*								
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*								
Number of Passes	*3*	*3*	*3*								
Power Level (amps/volts)	*2000-2300*	*2100-2300*	*2100*								
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*								
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*								
Stand Off (in)	*2.19*	*2.19*	*2.19*								
Index Distance (in)	*11*	*11*	*11*								

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

Zone 1: 1st pass at 2100 removes black-yellow primer, down to white layer (filler); 2nd pass at 2300 no difference from initial pass; 3rd pass at 2000 black taken off, yellow showing, no white visible. Layers: black – yellow – white. Requires 2 passes to strip down to primer.

Zone 2: 1st pass at 2300, 2nd pass at 2300, 3rd pass at 2100 (from9"-22" used flash; again from 106" to 165"; and from 177"-237").

Zone 3: 1ST pass at 2100; 2nd pass at 2100; 3rd pass at 2100. Center areas dark after second pass (repair suspected, visible paint chips). After third pass, center remains dark in color.

Notes:

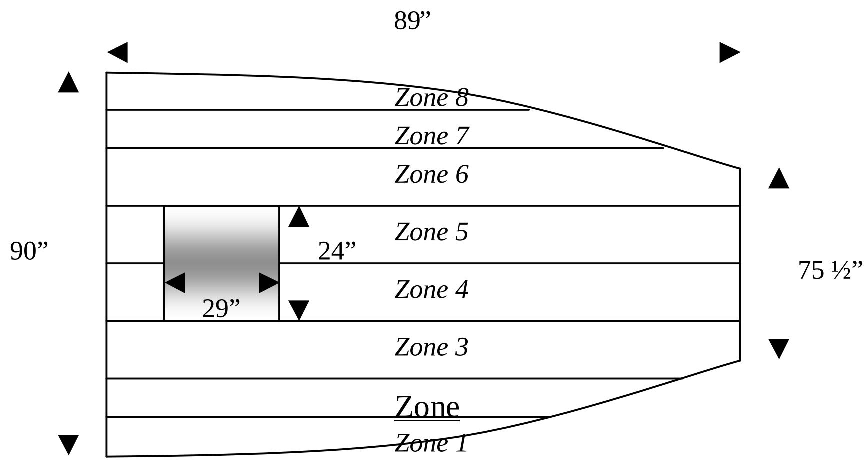
Stripping bottom of the rotor blade. Suspected repair at beginning of blade – filler (white in color) visible (zone 1, approx. point 7).

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*2-3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*CH-53 Rear Door (Upper door)*

<u>Test Setup</u>

(Designate scan paths by hand on sketch below)



<u>Pre-test check</u>

Coating Thickness Survey

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*3.1*	*3.1*	*3.5*	*3.5*	*3.6*	*4.0*	*4.3*				*3.58*
Zone 2	*2.9*	*3.2*	*3.4*	*3.5*	*3.4*	*3.8*	*4.6*	*4.4*			*3.65*
Zone 3	*4.0*	*4.0*	*3.7*	*4.5*	*4.2*	*4.4*	*5.0*	*4.4*			*4.28*
Zone 4	*3.0*	--	--	*4.4*	*4.1*	*4.6*	*5.3*	*5.9*			*4.55*
Zone 5	*3.0*	--	--	*5.3*	*5.9*	*5.4*	*5.6*	*5.4*			*5.10*
Zone 6	*3.7*	*3.4*	*3.5*	*4.8*	*4.7*	*4.4*	*5.5*	*4.6*			*4.32*
Zone 7	*3.8*	*3.9*	*3.7*	*4.0*	*4.0*	*4.0*	*4.7*	*4.6*			*4.09*
Zone 8	*3.7*	*4.6*	*4.3*	*4.6*	*4.7*	*4.3*	*5.6*				*4.54*
Zone 9											
Zone 10											

Test Data

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)								*Limitation due to drop off to the left of the test par.*			
% Stripped (visual)	*10 - 88*	*20 80 95-7*	*10 25 97*	*15 30 97*	*10 - 99*	*15 50 99*	*10 20 -*				
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*				
Number of Passes	*3*	*3*	*3*	*3*	*3*	*3*	*3*				
Power Level (amps/volts)	*2100 2100 2100*	*2300 2300 2300*	*2300 2100 2100*	*2300 2100 2100*	*2300 2100 2100*	*2300 2100 2100*	*2300 2100 2100*				
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*				
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*				
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*				
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*				

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

Pass 1 (zone 1): not much paint removed (2-3 patches). Pass 3 removed about 88%. More efficient if zone was flat instead of curved, drop off. A combination of power levels 2300 (as pass 1) – 2100 (as pass 2) – 2100 (as pass 3) seems to provide the best results. The initial pass removes the gloss.

Notes:

*According to Boeing personnel, lamp is guaranteed for 500,000 flashes, which is directly dependent on the power level at which the lamp is operated. (*Normally get 1 million flashes out of lamps.) Lamp costs of $750/lamp; lamp window costs of $250/lamp (lamp windows only need changed when the paint being stripped splashes back onto the lamp and produces a gummy film).*

After FLASHJET®:

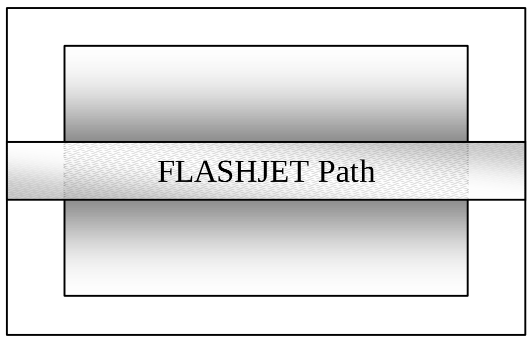
Zone Points	1	2	3	4	5	6	7	8	Avg.
Z1: After 2 Passes (2300,2100)	0.6	0.5	0.7	0.7	1.0	1.2	1.5	--	0.88
Z3: After 1 Pass (2300)	2.3	2.8	2.7	1.9	2.3	1.3	1.9	1.1	2.04
Z6: After 3 Passes (2300,2100,2100)	0.2	0.3	0.4	0.3	0.5	0.6	0.9	0.5	0.46

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*CH-53 Personnel Door (**plexi glass, test piece**)*

<u>Test Setup</u>

(Designate scan paths by hand on sketch below)



Note: This piece consisted mostly of plexi glass. Wanted to test FLASHJET® on part to determine how the process affected plexi glass.

Before: Visible glue on part, as well as small masking remains.

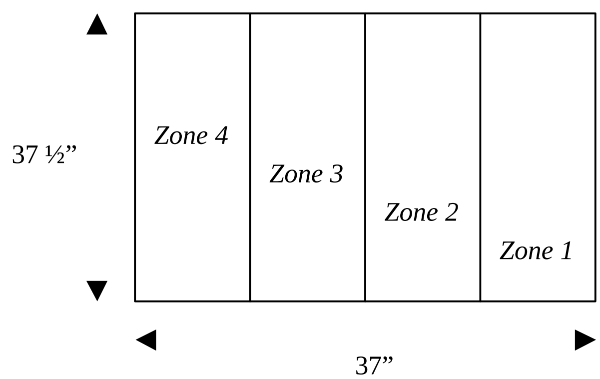
After: Only 2 passes (both at 2300) were completed. Turned glue opaque. Otherwise, no effect on part.

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*CH-53 Personnel Door*

<u>Test Setup</u>

(Designate scan paths by hand on sketch below)



<u>Pre-test check</u>

Coating Thickness Survey

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*3.7*	*2.9*	*3.0*								*3.2*
Zone 2	*5.1*	*3.2*	*2.6*								*3.63*
Zone 3	*3.9*	*2.8*	*2.9*								*3.2*
Zone 4	*11.0*	*8.4*	*16.9*								*12.1*
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

Test Data

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)				***Limitation due to test set-up (clamps holding part).***							
% Stripped (visual)	*25* *95*	*55* *95*	*25* *95*								
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*								
Number of Passes	*2*	*2*	*2*								
Power Level (amps/volts)	*2300* *2100*	*2300* *2100*	*2300* *2100*								
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*								
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*								
Stand Off (in)	*2.19*	*2.19*	*2.19*								
Index Distance (in)	*11*	*11*	*11*								

Visual Inspection:

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

Set-up does not allow for stripping of Zone 4.

Notes:

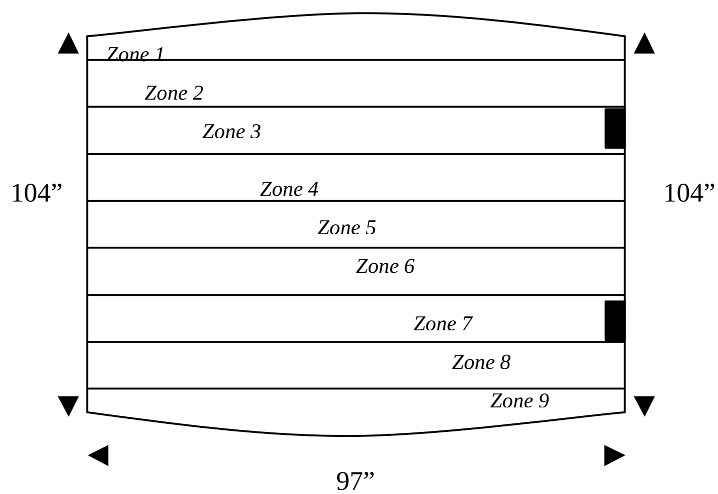
N/A

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*Ch-53 Cargo Ramp*

Test Setup

(Designate scan paths by hand on sketch below)



Pre-test check

Coating Thickness Survey

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*3.1*	*2.4*	*2.9*	*3.7*	*2.4*						*2.9*
Zone 2	*2.5*	*2.4*	*3.1*	*3.9*	*3.0*						*2.98*
Zone 3	*2.4*	*2.4*	*2.7*	*3.5*	*3.6*						*2.92*
Zone 4	*2.5*	*2.9*	*5.0*	*4.1*	*3.9*						*3.68*
Zone 5	*2.8*	*2.8*	*3.9*	*4.5*	*3.8*						*3.56*
Zone 6	*3.0*	*3.0*	*4.4*	*4.6*	*4.2*						*3.84*
Zone 7	*3.4*	*2.5*	*4.1*	*3.8*	*3.3*						*3.42*
Zone 8	*2.9*	*3.3*	*5.3*	*4.4*	*3.0*						*3.78*
Zone 9	*2.7*	*3.0*	*3.2*	*2.7*	*2.1*						*2.74*
Zone 10											

Test Data

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)	*Limitation due to test specimen shape (drop off)*	*Limitation due to test specimen shape (drop off)*						*Limitation due to test specimen shape (drop off).*	*Limitation due to test specimen shape (drop off)*		
% Stripped (visual)			*90 100*	*70 **	***80*	***90*	*†100*				
Robot Traverse Rate (in/sec)			*0.9*	*0.9*	*0.9*	*0.9*	*0.9*				*0.9*
Number of Passes			*3*	*2*	*1*	*1*	*1*				*1.6*
Power Level (amps/volts)			*2300 2100 2100*	*2100 2100/ 2300*	*2100*	*2100*	*2100*				*2144*
CO_2 Consumption (lbs./hr)			*700*	*700*	*700*	*700*	*700*				*700*
Flash Frequency (Hz)			*3.6*	*3.6*	*3.6*	*3.6*	*3.6*				*3.6*
Stand Off (in)			*2.19*	*2.19*	*2.19*	*2.19*	*2.19*				*2.19*
Index Distance (in)			*11*	*11*	*11*	*11*	*11*				*11*

Visual Inspection:

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

"*Bondo*" is visible after stripping; sealant around connections is visible; dark primer; stripped down to substrate after 3rd pass. Flashlamp malfunctioned at 33 in. during second pass of zone # 4. Bulb, quartz water jacket, and quartz window replaced. Finished 2nd pass of zone #4 at 2300 volts. *Area stripped to bare metal.

Notes:

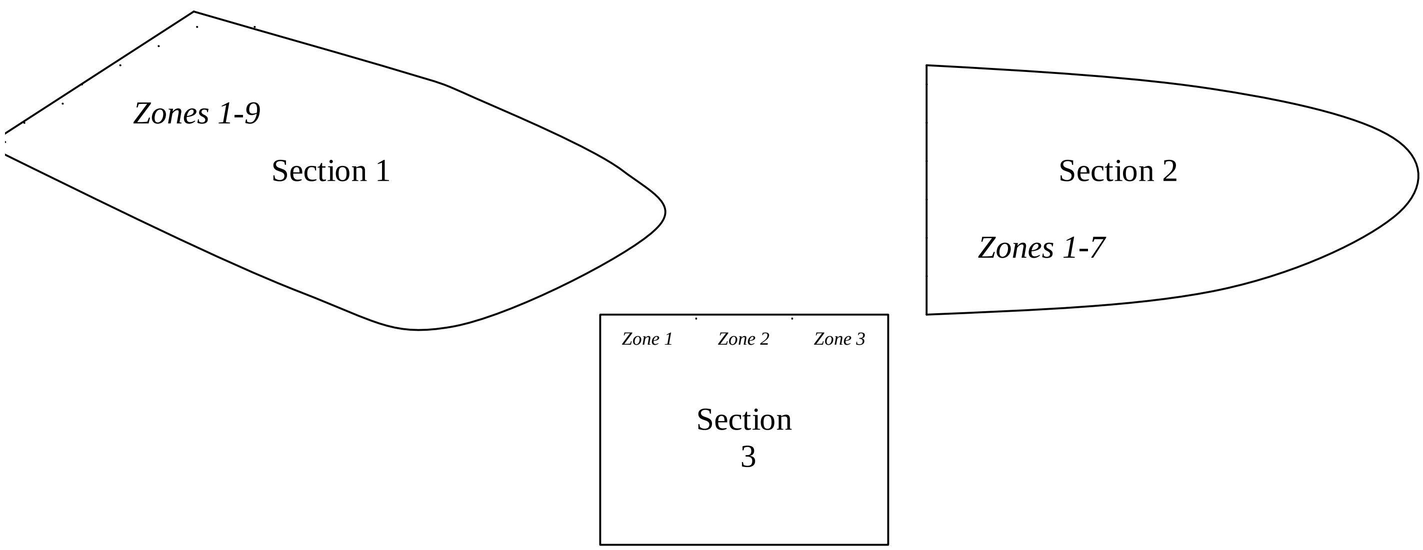
Cannot strip zones 1-2-8-9 due to test specimen shape (drop off). This could be done very easily at Mesa facility. St. Louis facility does not have 7th axis, which allows the FLASHJET® head to conform to drop off edges. **Indicates percentage of primer remaining †Pellet loss at zone 7 after 31 in. Reestablished pellet flow and resumed pass at 31 in. Removed 100% topcoat leaving primer intact.

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*CH –53 Pylon*

<u>Test Setup</u>

(Designate scan paths by hand on sketch below)



<u>Pre-test check</u>

Coating Thickness Survey (Section 1)

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*2.0*	*2.0*	*2.5*	*2.8*	*2.2*	*1.9*	*1.9*	*1.9*	*2.2*		*2.16*
Zone 2	*2.1*	*2.2*	*2.6*	*2.4*	*2.3*	*1.9*	*1.8*	*1.8*	*2.5*		*2.18*
Zone 3	*2.0*	*2.5*	*2.2*	*2.4*	*2.4*	*1.9*	*1.9*				*2.18*
Zone 4											
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

Pre-test check

Coating Thickness Survey (Section 2)

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*1.5*	*1.3*	*1.2*	*1.2*	*1.2*	*1.9*	*1.8*				*1.37*
Zone 2	*2.2*	*2.4*	*2.7*	*1.6*	*1.1*	*1.5*	*2.1*				*1.94*
Zone 3	*1.7*	*1.8*	*1.4*	*2.1*	*1.1*	*1.9*	*2.3*				*1.74*
Zone 4											
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

Pre-test check

Coating Thickness Survey (Section 3)

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1	*1.2*	*1.4*	*1.3*								*1.30*
Zone 2	*1.0*	*1.0*	*1.1*								*1.03*
Zone 3	*1.2*	*0.9*	*1.2*								*1.10*
Zone 4											
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

Test Data
(Section 1)

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*90*	*90*	*90*								*90*
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*								*0.9*
Number of Passes	*1*	*1*	*1*								*1*
Power Level (amps/volts)	*1900*	*1900*	*1900*								*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*								*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*								*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*								*2.19*
Index Distance (in)	*11*	*11*	*11*								*11*

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

Zone/Pass began at rear of pylon and progressed toward leading edge. Excellent production quality strip over Section 1.

Notes:

N/A

Test Data
(Section 2)

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*	*	*	*	*	*	*	*	*90*	*90*	
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Number of Passes	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:
Zones began at bottom of radius to middle flat for 1 thru 4. Zones began at middle of flat to bottom of radius for 5 thru 8. Zones 9 and 10 were approached at an angle across the leading edge. Number of zones required due to configuration of robot. Production robot would allow for Zones 1 and 5 to be incorporated into one pass.

Notes:

Excellent production quality strip on flat areas. Visible metal on curves is not recommended for production stripping. Reduced voltage and additional passes will correct this on robot. Standoff is more precise on production robot. *Stripped to metal on curve, to primer on flat.

Test Data
(Section 3)

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*50*	*50*	*50*								*50*
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*								*0.9*
Number of Passes	*1*	*1*	*1*								*1*
Power Level (amps/volts)	*1900*	*1900*	*1900*								*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*								*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*								*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*								*2.19*
Index Distance (in)	*11*	*11*	*11*								*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:
Coating was green primer with no topcoat. This side is an internal structure, not normally depainted/repainted. There is no evidence of repaint on this surface.

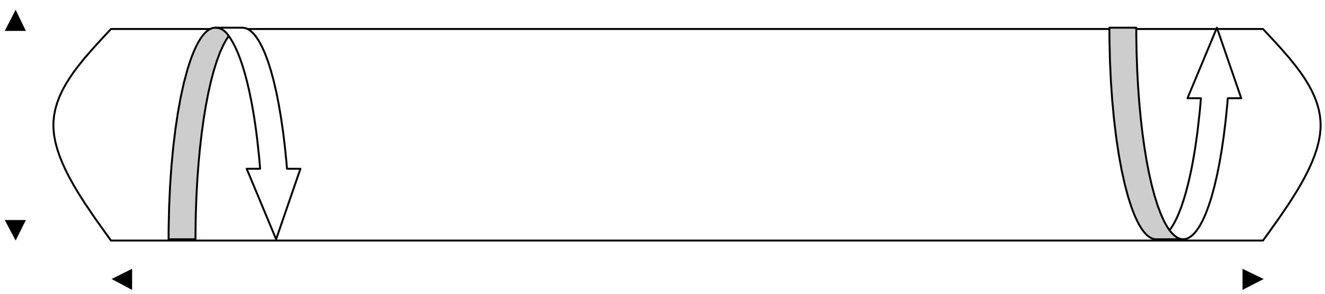
Notes:
N/A

Project Title: Validation of an Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process

Operator Name	D. Breihan
Date/Time	*3 February 1999*
Facility Location	*Boeing, St. Louis, Building 101*
Test Specimen	*Auxiliary Fuel Tank*

Test Setup

(Designate scan paths by hand on sketch below)



Pre-test check

Coating Thickness Survey

CAN NOT PERFORM DUE TO SUBSTRATE TYPE!

Point	1	2	3	4	5	6	7	8	9	10	Avg.
Zone 1											
Zone 2											
Zone 3											
Zone 4											
Zone 5											
Zone 6											
Zone 7											
Zone 8											
Zone 9											
Zone 10											

Test Data
(Section 1 - Cylindrical Portion)

Zone	1	2	3	4	5	6	7	8	9	10	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*1-40 2-70*	*1-40 2-80*	*90*	*90*	*90*	*90*	*90*	*90*	*90*	*90*	
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Number of Passes	*2*	*2*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

The cylinder was programmed in 15 zones. Each zone length is 37 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. The following matrix is structured as follows: Zones 1 thru 15 are for the top 120°. The tank was then rotated 120°. Zones 16 thru 30 are for the second 120°. The tank was then rotated 120°. Zones 31 thru 45 are for the third 120°.

Notes:

With the exception of zones 1 and 2, only one pass was made. This one pass is representative of a production strip where approximately 10% of the coating is left intact. Zones 1 and 2 required 2 passes because of less than optimal standoff.

Test Data
(Section 1 - Cylindrical Portion - continued)

Zone	11	12	13	14	15	16	17	18	19	20	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*90*	*90*	*90*	*90*	*90*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Number of Passes	*1*	*1*	*1*	*1*	*1*	*3*	*3*	*3*	*3*	*3*	
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations: (same as previous - data continued on following page):
The cylinder was programmed in 15 zones. Each zone length is 37 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. The following matrix is structured as follows: Zones 1 thru 15 are for the top 120°. The tank was then rotated 120°. Zones 16 thru 30 are for the second 120°. The tank was then rotated 120°. Zones 31 thru 45 are for the third 120°.

Notes: (data continued on following page):
Zones 16 thru 30 were stripped to substrate. While not necessary to achieve production quality results, all coatings were removed to demonstrate that fiberglass structures are particularly tolerant of the FLASHJET process. The third pass would not be recommended on metallic structures.

Test Data
(Section 1 - Cylindrical Portion - continued)

Zone	21	22	23	24	25	26	27	28	29	30	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Number of Passes	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations: (same as previous - data continued on following page)

The cylinder was programmed in 15 zones. Each zone length is 37 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. The following matrix is structured as follows: Zones 1 thru 15 are for the top 120°. The tank was then rotated 120°. Zones 16 thru 30 are for the second 120°. The tank was then rotated 120°. Zones 31 thru 45 are for the third 120°.

Notes: (same as previous - data continued on following page)

Zones 16 thru 30 were stripped to substrate. While not necessary to achieve production quality results, all coatings were removed to demonstrate that fiberglass structures are particularly tolerant of the FLASHJET process. The third pass would not be recommended on metallic structures.

Test Data
(Section 1 - Cylindrical Portion - continued)

Zone	31	32	33	34	35	36	37	38	39	40	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Number of Passes	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations: (same as previous - data continued on following page)

The cylinder was programmed in 15 zones. Each zone length is 37 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. The following matrix is structured as follows: Zones 1 thru 15 are for the top 120°. The tank was then rotated 120°. Zones 16 thru 30 are for the second 120°. The tank was then rotated 120°. Zones 31 thru 45 are for the third 120°.

Notes: (same as previous - data continued on following page)

Zones 16 thru 30 were stripped to substrate. While not necessary to achieve production quality results, all coatings were removed to demonstrate that fiberglass structures are particularly tolerant of the FLASHJET process. The third pass would not be recommended on metallic structures.

Test Data
(Section 1 - Cylindrical Portion - end)

Zone	41	42	43	44	45	-	-	-	-	-	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*						
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*						*0.9*
Number of Passes	*3*	*3*	*3*	*3*	*3*						*3*
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*						*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*						*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations (same as previous):
The cylinder was programmed in 15 zones. Each zone length is 37 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. The following matrix is structured as follows: Zones 1 thru 15 are for the top 120°. The tank was then rotated 120°.
Zones 16 thru 30 are for the second 120°. The tank was then rotated 120°.
Zones 31 thru 45 are for the third 120°.

Notes (same as previous):
Zones 16 thru 30 were stripped to substrate. While not necessary to achieve production quality results, all coatings were removed to demonstrate that fiberglass structures are particularly tolerant of the FLASHJET process. The third pass would not be recommended on metallic structures.

Test Data
(Section 2 - Nose Taper)

Zone	1	2	3	4	5	6	-	-	-	-	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*90*	*90*	*1-90* *2-90* *3-100*	*1-90* *2-90* *3-100*	*1-90* *2-90* *3-100*	*1-90* *2-90* *3-100*					
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*					*0.9*
Number of Passes	*1*	*1*	*3*	*3*	*3*	*3*					
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*					*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*					*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*					*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*					*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*					*11*

Visual Inspection

(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:

The nose was programmed in 2 zones. Each zone length is 34 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. Nose tip to 27 inches aft was not stripped. The following matrix is structured as follows: Zones 1 and 2 are for the top 120°. The tank was then rotated 120°. Zones 3 and 4 are for the second 120°. The tank was then rotated 120°. Zones 5 and 6 are for the third 120°.

Notes:

N/A

Test Data
(Section 3 - Tail Taper)

Zone	1	2	3	4	5	6	-	-	-	-	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*90*	*90*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*	*1-90 2-90 3-100*					
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*					*0.9*
Number of Passes	*1*	*1*	*3*	*3*	*3*	*3*					
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*	*1900*	*1900*					*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*	*700*	*700*					*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*	*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:
The tail was programmed in 2 zones. Each zone length is 34 inches or approximately 120° of the total circumference. The program was repeated 3 times to strip the total circumference. Nose tip to 30 inches fwd was not stripped. The following matrix is structured as follows: Zones 1 and 2 are for the top 120°. The tank was then rotated 120°. Zones 3 and 4 are for the second 120°. The tank was then rotated 120°. Zones 5 and 6 are for the third 120°.

Notes:
N/A

Test Data
(Section 4 - Winglets)

Zone	1	2	3	4	5	6	-	-	-	-	Avg.
Stripped Surface Area (in^2)											
% Stripped (visual)	*1-50 2-90*	*1-50 2-90*	*1-50 2-90*	*1-50 2-90*							
Robot Traverse Rate (in/sec)	*0.9*	*0.9*	*0.9*	*0.9*							*0.9*
Number of Passes	*2*	*2*	*2*	*2*							*2*
Power Level (amps/volts)	*1900*	*1900*	*1900*	*1900*							*1900*
CO_2 Consumption (lbs./hr)	*700*	*700*	*700*	*700*							*700*
Flash Frequency (Hz)	*3.6*	*3.6*	*3.6*	*3.6*							*3.6*
Stand Off (in)	*2.19*	*2.19*	*2.19*	*2.19*							*2.19*
Index Distance (in)	*11*	*11*	*11*	*11*							*11*

Visual Inspection
(Inspect surface for signs of damage such as burning or fraying of composite or fiberglass, decoating around rivets and general appearance)

Observations:
The top surfaces of the left and right winglets were stripped for demonstration purposes only. These structures are solid aluminum. The current FLASHJET head can only access about one-third of the total area. Also, programming time was excessive. These winglets can be hand sanded or left alone.

Notes:

A small percentage of the tank was not stripped due to protrusions and the lack of one additional axis on the robot. As stated before, production robots will afford greater access. Overall stripping quality appears to be excellent.

SH-60 Seahawk Data Summary

The following pages show the results of the SH-60 Seahawk demonstration in Mesa, AZ in accordance with parameters set in the Joint Test Protocol. Due to the large number of scan and strip paths in this demonstration, the data sheets were not used however data from each scan and strip path was documented.

SH60.001 – LEFT UNDERSIDE CENTER FROM DOPPLER TO LANDING GEAR
Teach Time: 2 hours
Strip Time: 4 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	8	8	6	1	4
1.5 (5.5” Index)	4	8	4 4	0.75 1	3 4
2	8	8	2	1	4
2.5 (5.5” Index)	4	8	3 3	0.75 1	3 3
3	8	8	8 2	0.75 1	3 4

IPS – Inches Per Second

SH60.002 – LEFT UNDERSIDE FROM TURTLEBACK TO LANDING GEAR
Teach Time: 1 hour
Strip Time: 1.5 hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	14	8	6	1	4
1.5 (5.5” Index)	7	8	6	1	4
2	14	8	6	1	4

SH60.003 – UNDERSIDE LEFT OF DOPPLAR
Teach Time: 1 hour
Strip Time: 1.5 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	8	7	1	4

SH60.004 – RIGHT UNDERSIDE CENTER FROM HOLE TO LANDING GEAR
Teach Time: 2 hours
Strip Time: 2 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	8	8	6	1	4
1.5 (5.5” Index)	4	8	3	1	4
2	8	8	5	1	4
2.5 (5.5” Index)	4	8	3	1	4
3	8	8	5	1	4

SH60.005 – RIGHT SIDE TAIL TEST (NEW REFLECTOR INSTALLED)
Teach Time: 0.5 hours
Strip Time: 0.5 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	6	7	4	1	4
	6	6	4	1	4

SH60.006 – RIGHT UNDERSIDE FROM TURTLEBACK TO HOLE
Teach Time: 0.5 hours
Strip Time: 0.5 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	10	8	4	1	4

SH60.007 – RIGHT UNDERSIDE FROM HOLE TO LANDING GEAR
Teach Time: 0.5 hours
Strip Time: 0.5 hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	8	8	4	1	4

SH60.008 – RIGHT UNDERSIDE FROM HOLE TO LANDING LIGHT
Teach Time: 1.5 hours
Strip Time: 1 hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	6	8	4	1	4
1.5 (5.5” Index)	3	9	2	1	4
2	6	8	8	1	4
2.5 (5.5” Index)	3	8	6	1	4

SH60.009 – RIGHT UNDERSIDE BELOW DOOR OPENING
Teach Time: 1 hour
Strip Time: 1 hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	9	7	1	4
2	4	8	6	1	4

SH60.010 – LEFT UNDERSIDE FROM LANDING GEAR TO NOSE
Teach Time: 2 hours
Strip Time: 1 hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	7	5	1	4
2	5	8	4	1	4
3	5	9	6	1	4
4	5	7	5	1	4
Front of Aircraft	-	-	-	-	-
1	3	9	5	1	4
2	3	9	5	1	4
3	3	8	3	1	4
4	3	9	4	1	4

SH60.011 – RIGHT UNDERSIDE FROM LANDING GEAR TO NOSE

Teach Time: 1.25 Hours
Strip Time: 1 Hour
Standoff Distance: 2.19"
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001")	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	9	3	1	4
2	5	8	2	1	4
3	5	9	4	1	4

SH60.012 – RIGHT UNDERSIDE BEHIND DOOR OPENING

Teach Time: 0.5 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19"
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001")	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	9	1	4

SH60.013 – LEFT SIDE UNDER FRONT DOOR

Teach Time: 1 hour
Strip Time: 1 hour
Standoff Distance: 2.19"
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001")	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	8	5	1	4
2	4	8	6	1	4
3	4	8	6	1	4

SH60.014 – RIGHT SIDE FWD OF LANDING GEAR

Teach Time: 1 Hour
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	7	3	1	4
2	4	8	5	1	4
3	4	7	5	1	4

SH60.015 – UNDER RIGHT SIDE OF NOSE

Teach Time: 0.75 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	9	3	1	4
2	2	9	5	1	4

SH60.016 – LEFT SIDE OF TAIL

Teach Time: 1 Hour
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	6	6	10	1	4
2	6	6	2	1	4

SH60.017 – UPPER LEFT SIDE OF TAIL

Teach Time: 1 Hour
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	7	8	1	4
2 (3” Index)	1	8	4	1	4

SH60.018 – LEFT SIDE OF TAIL ABOVE CENTER

Teach Time: 2 Hours
Strip Time: 2 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	9	5	1	4
2 (3” Index)	1	8	3	1	4

SH60.018+ - Continued Sections for SH60.018

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1 (2050 V)	3	9	2	1	4
2 (1900 V)	1	8	5	1	4

SH60.019 – LEFT TAIL LOWER FWD

Teach Time: 1.5 Hours
Strip Time: 1.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	5	1	4

SH60.019+ - Continued Sections for SH60.019

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	5	1	4
2 (2.5” Index)	1	8	3	1	4
3 (1900 V)	3	8	4	1	4

SH60.020 – FORWARD LEFT TAIL

Teach Time: 1 Hour
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	7	5	1	4
2 (1.8” Index)	1	7	4	1	4

SH60.021 – LEFT SIDE TAIL TRANSITION
Teach Time: 2 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	7	6	1	4
2 (6” Index)	1	7	8	1	4

SH60.022 – LEFT AFT BODY FORWARD TO TRANSITION
Teach Time: 2.5 Hours
Strip Time: 3 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	10	5	1	4
2 (2.5” Index)	2	10	3	1	4
3 (1900 V)	5	9	4	1	4

SH60.023 – LEFT SIDE AFT OF WING STAB – PART 1
Teach Time: 0.25 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	10	1	4
2 (5” Index)	2	8	3	1	4
3 (2.5” Index)	1	8	8	1	4
4 (7.5” Index)	2	8	9	1	4

<u>SH60.024 – LEFT SIDE AFT OF WING STAB – PART 2</u>

Teach Time: 0.75 Hours
Strip Time: 0.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	4	1	4
2 (6” Index)	2	8	5	1	4

<u>SH60.025 – LEFT SIDE ABOVE WING STAB</u>

Teach Time: 1.5 Hours
Strip Time: 2 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	8	6	1	4
2 (6” Index)	3	8	5	1	4
3 (6” Index)	3	8	10	1	4
4 (6” Index)	3	8	2	1	4
5	3	8	3	1	4
6	3	8	3	1	4
7	3	8	4	1	4

<u>SH60.026 – LEFT SIDE BELOW WINDOW</u>

Teach Time: 3 Hours
Strip Time: 1.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	7	8	1	4
2 (5.5” Index)	2	7	2	1	4
3 (5.5” Index)	2	7	8	1	4
4 (5.5” Index)	2	7	5	1	4
5 (5.5” Index)	2	7	9	1	4

SH60.027 – VERTICAL STABILIZER
Teach Time: 3.5 Hours
Strip Time: 2 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	7	10	1	4
2	4	7	12	1	4
3	4	7	13	1	4
4	4	7	13	1	4
5	4	7	12	1	4
6	4	7	13	1	4
7	4	7	14	1	4
8	4	7	11	1	4
9	4	7	13	1	4

SH60.028 – LEFT SIDE FWD OF WINDOW
Teach Time: 1 Hour
Strip Time: 2 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	8	15	1	4
2	5	8	15	1	4

SH60.029 – LEFT SIDE AFT OF DOOR
Teach Time: 2 Hours
Strip Time: 2 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	6	4	7	1	4
2	6	5	7	1	4
3	6	7	6	1	4
4	6	4	7	1	4

SH60.030 – LEFT SIDE ABOVE WING STAB (NO HALO)
Teach Time: 1.5 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	8	1	4

SH60.031 – LEFT SIDE FWD OF ENGINE DOOR HINGE
Teach Time: 1.5 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	15	8	10	1	4

SH60.032 – TOP LEFT VER STAB
Teach Time: 0.75 Hours
Strip Time: 0.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	11	1	4

SH60.033 – LEFT VERT STAB FWD OF HORIZONTAL
Teach Time: 0.5 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	6	14	1	4
2	2	6	10	1	4

SH60.034 – AFT OF LEFT VERT ATTACH
Teach Time: 0.5 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	7	8	1	4
2 (10” Index)	2	8	10	1	4

SH60.035 – FWD OF LEFT VERT ATTACH
Teach Time: 0.75 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	8	11	1	4
2 (7” Index)	2	8	8	1	4

SH60.036 – TOP AFT EDGE OF RIGHT SIDE VERT
Teach Time: 1 Hour
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	10	13	1	4

SH60.037 – FWD EDGE OF RIGHT SIDE VERT
Teach Time: 1 Hour
Strip Time: 1.5 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	9	10	1	4
2	3	8	9	1	4

SH60.038 – RIGHT VERT ATTACH
Teach Time: 1.5 Hours
Strip Time: 1.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	7	8	15	1	4
2	5	9	15	1	4
3	5	8	15	1	4
4	5	8	12	1	4

SH60.039 – RIGHT VERT UNDER HORIZONTAL
Teach Time: 0.5 Hours
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	8	15	1	4
2 (5.5” Index)	2	9	15	1	4
3 (5.5” Index)	2	8	15	1	4
4 (5.5” Index)	2	8	15	1	4
5 (5.5” Index)	2	8	10	1	4

SH60.040 – LEFT UNDERSIDE FROM AFT LANDING GEAR TO TAIL
Teach Time: 3.5 Hours
Strip Time: 3.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	7	5	1	4
2 (28” Index)	1	7	7	1	4
3 (7” Index)	1	6	7	1	4
4 (10” Index)	1	6	5	1	4
5 (6” Index)	1	8	6	1	4
6 (10” Index)	1	5	7	1	4
7 (10” Index)	1	5	6	1	4
8 (10” Index)	1	6	6	1	4
9 (10” Index)	1	7	5	1	4

SH60.041 – RIGHT UNDERSIDE FROM AFT LANDING GEAR TO TAIL
Teach Time: 3.5 Hours
Strip Time: 3.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	7	5	1	4
2	2	8	5	1	4
3	2	7	7	1	4
4	2	7	7	1	4
5	2	6	8	1	4
6	2	5	7	1	4
7	None	None	None	None	None
8	None	None	None	None	None
9	2	6	12	1	4
10	2	5	10	1	4
11	2	7	12	1	4
12	2	7	13	1	4
13	2	8	11	1	4

SH60.041M – Continued Sections for SH60.041
Teach Time: 0.25 Hours
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	2	6	8	1	4
2	2	6	9	1	4
3	2	6	7	1	4
4	2	7	7	1	4
5	2	6	5	1	4

SH60.042 – RIGHT SIDE WING TO TAIL
Teach Time: 4 Hours
Strip Time: 2.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	7	10	1	4
2	4	5	9	1	4
3	4	5	11	1	4
4	4	4	10	1	4
5	4	5	10	1	4
6	4	5	10	1	4
7	4	6	10	1	4
8	4	7	10	1	4
9	4	7	12	1	4
10	4	7	10	1	4
11	4	7	10	1	4
12	4	8	11	1	4

SH60.043 – RIGHT SIDE FWD OF WING
Teach Time: 2 Hours
Strip Time: 1.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	5	10	1	4
2	4	6	10	1	4
3	3	6	10	1	4
4	3	8	12	1	4

SH60.044 – RIGHT SIDE AFT OF PYLON
Teach Time: 1.5 Hours
Strip Time: 1 Hour
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	5	9	1	4
2	4	5	7	1	4

SH60.045 – RIGHT SIDE FWD OF PYLON
Teach Time: 2 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	9	8	1	4
2	3	9	7	1	4
3	3	8	10	1	4

SH60.046 – RIGHT SIDE ABOVE PYLON
Teach Time: 2.5 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	7	8	1	4
2	2	7	8	1	4
3	2	8	8	1	4
4	2	7	7	1	4
5	2	7	6	1	4

SH60.047 – RIGHT SIDE AFT OF PYLON
Teach Time: 1 Hour
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	4	1	4
2	2	7	8	1	4
3	3	8	7	1	4

SH60.048 – RIGHT SIDE UNDER NACELLE

Teach Time: 0.75 Hours
Strip Time: 0.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	15	9	9	1	4

SH60.049 – RIGHT SIDE AFT OF FWD DOOR

Teach Time: 2 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	13	8	1	4
2	5	11	10	1	4
3	5	10	9	1	4

SH60.050 – RIGHT SIDE FWD OF AFT DOOR

Teach Time: 2 Hours
Strip Time: 0.75 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	5	10	11	1	4
2	5	10	13	1	4
3	5	11	6	1	4

SH60.051 – RIGHT SIDE ABOVE ACCESS DOOR

Teach Time: 0.75 Hours
Strip Time: 0.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	6	13	10	1	4

SH60.052 – RIGHT SIDE TOP OF TAIL BOOM
Teach Time: 0.5 Hours
Strip Time: 0.25 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	3	8	8	1	4
2	3	7	8	1	4

SH60.053 – RIGHT SIDE TAIL BOOM ABOVE WING
Teach Time: 1 Hour
Strip Time: 0.5 Hours
Standoff Distance: 2.19”
Input Voltage: 2050 V

Zone Number	Approximate Area (ft^2)	Average Paint Thickness (0.001”)	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
1	4	7	8	1	4

Appendix C
Joint Test Report – M113 Armored Personnel Carrier

Appendix C of this Final Report contains the Joint Test Report for the M113 Armored Personnel Carrier. Included in this Joint Test Report are all data collected in the demonstration, a comparison of the pre-testing requirements and actual data, and recommendations on how to improve the FLASHJET® process for use on M113 Armored Personnel Carriers and other Army/Marine Corps ground/fighting vehicles.

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Environmental Security Technology Certification Program (ESTCP)

Joint Test Report

For Validation of An Alternative to Hazardous Media for Depainting Activities on Military Applications Using the FLASHJET® Coatings Removal Process:

M113 Armored Personnel Carrier

16 August 2000

C3

FINAL

PREFACE

This report was prepared by Peter M. Stemniski, P.E. of the U.S. Army Aberdeen Test Center. This report was prepared on behalf of, and under guidance provided by, the Environmental Security Technology Certification Program (ESTCP). The structure, format, and depth of the technical content of the report was determined by the ESTCP, Government contractors, and other Government technical representatives in response to the specific needs of this project.

We wish to acknowledge the invaluable contributions provided by the following organizations involved in the creation of this document:

- U.S. Army Environmental Center – Aberdeen Proving Ground, MD
- U.S. Aberdeen Test Center – Aberdeen Proving Ground, MD
- Anniston Army Depot – Anniston, AL
- Fort Hood Environmental Office – Fort Hood, TX
- Corpus Christi Army Depot – Corpus Christi, TX
- U.S. Army Tank-automotive and Armaments Command – Warren, MI
- Army Acquisition Pollution Prevention Support Office – Alexandria, VA
- The Boeing Company – St. Louis, MO
- Platinum International, Inc. – Alexandria, VA
- National Defense Center for Environmental Excellence – Johnstown, PA

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EXECUTIVE SUMMARY

In October 1997, the Environmental Security Technology Certification Program awarded the U.S. Army Environmental Center a project to demonstrate and validate the Flash Tech, Inc. (formerly The Boeing Company) FLASHJET® Coatings Removal Process on military equipment, specifically on rotary wing and ground/fighting vehicle applications. The FLASHJET® process, originally patented by the McDonnell-Douglas Corporation, combines the xenon-flashlamp and carbon dioxide (dry ice) pellet blasting technologies into an environmentally acceptable coatings removal process.

Technical representatives from affected ground/fighting vehicle programs agreed to minimal testing requirements that would qualify the FLASHJET® process on ground/fighting vehicles. These requirements can be found in the Joint Test Protocol.

In this demonstration/validation, the FLASHJET® process was evaluated on one M113 Armored Personnel Carrier supplied by the Anniston Army Depot. Results from the demonstration show that the FLASHJET® process is a viable coating removal process with some minor engineering changes to the FLASHJET® stripping head.

1. INTRODUCTION

The FLASHJET® process was developed in 1991 by a team of engineers from the McDonnell Douglas Corporation, Maxwell Laboratories, and Cold Jet, Inc. The FLASHJET® process combines the use of the xenon-flashlamp and carbon dioxide coatings removal technologies into one process. The process consists of six components including the flashlamp and stripping head, the manipulator robotic arm, the computer processing cell controller, the effluent capture system, the carbon dioxide pelletizer, and the power supply for the system.

The ground/fighting vehicle portion of the demonstration occurred in May 2000 at the newly installed aircraft FLASHJET® facility at the Corpus Christi Army Depot, TX. One M113 Armored Personnel Carrier (APC) categorized as Condition Code “P” was supplied by the Anniston Army Depot, AL for this demonstration/validation. Originally one M1A1 Abrams, one Bradley Fighting Vehicle, and one High Mobility Multipurpose Wheeled Vehicle were planned to be evaluated in this demonstration/validation but due to funding limitations, the project team decided to demonstrate the FLASHJET® process on one M113 APC. Results from the M113 APC demonstration would determine if the FLASHJET® process is an acceptable coatings removal process alternative for all U.S. Army and U.S. Marine Corps ground/fighting vehicles.

2. PERFORMANCE AND TESTING REQUIREMENTS

A joint group led by the Environmental Security Technology Certification Program and consisting of technical representatives from the affected Program Managers, Anniston Army Depot, U.S. Army Tank-automotive and Armaments Command, and other government technical representatives identified engineering performance and operational impact (supportability) requirements for coating removal processes. This group then reached a consensus on tests to qualify potential alternatives against these technical requirements including procedures, methodologies, and acceptance criteria as applicable.

The following table represents the performance and test requirements for the M113 APC demonstration as found in the Joint Test Protocol (JTP).

Table 1: Joint Test Protocol Performance and Test Requirements

Test Category	Test Name	JTP Section	Acceptance Criteria	References
Effectiveness Tests	Coatings Removal	3.1.1	Coating material removed completely, no damage to underlying substrate	None
	Selective Coatings Removal	3.1.2	Topcoat layer removed, no damage to underlying primer layer	None
	Strippable Area Assessment	3.1.3	At least 80% of surface area stripped	None

3. TEST RESULTS

All results collected from the demonstration were evaluated against Sections 3.1.1; 3.1.2; and 3.1.3 of the JTP. Section 5 of this Joint Test Report contains all data from the demonstration including all estimated program and strip times, approximate stripping areas, coating thicknesses, input voltages, FLASHJET® stripping head standoff distances, and number of passes required to depaint each section.

Section 3.1.1 of the JTP specified that all coating (both primer and topcoat) must be removed with no damage to the underlying substrate. Front sections of the M113 APC were evaluated against this acceptance criteria. All sections with complete coating removal were visually evaluated for damage to the underlying substrate. No sections showed signs of substrate damage. The acceptance criteria for Section 3.1.1 was met.

Section 3.1.2 of the JTP specified for only topcoat removal with no damage to the underlying primer. The two sides of the M113 APC were visually evaluated against this acceptance criteria. Both sections were stripped cleanly to the primer and showed no signs of damage to the underlying primer. The acceptance criteria for Section 3.1.2 was met.

Section 3.1.3 of the JTP specified that at least 80% of the equipment's surface area must be stripped using the FLASHJET® process. In this demonstration, approximately 50% of the external surface area was stripped due to some stripping limitations. Some limitations included stripping head spacing limitations due protrusions on the buggy the M113 APC was resting on and the size of the digital camera that was installed on the front of the FLASHJET® stripping head. Since only 50% of the external surface area was stripped using the FLASHJET® process, this did not meet the acceptance criteria for 3.1.3. It should be noted that engineering design changes can be made to the stripping head that would allow for more surface area, both internal and external, to be stripped using the FLASHJET® process.

4. SUMMARY AND RECOMMENDATIONS

The results from the M113 APC demonstration show that the FLASHJET® process is a viable alternative for stripping ground/fighting vehicle hulls as a primary coating removal process. Even though the acceptance criteria for Section 3.1.3 of the JTP was not met, some minor engineering design changes to the FLASHJET® stripping head could allow for more than 90% stripping of external surface area. A smaller stripping head would also allow for stripping inside the M113 APC hull and other ground/fighting vehicle hulls.

A secondary coating removal process will be required if using the FLASHJET® process on ground/fighting vehicles. One potential secondary coating removal process that can be implemented with the FLASHJET® process is the use of a portable laser coating removal system. The portable laser coating removal system will be able to remove the coating in areas where the FLASHJET® stripping head could not reach due to spacing limitations.

5. M113 APC DATA SUMMARY

The following pages show the results of the M113 APC demonstration in Corpus Christi, TX in accordance with parameters set in the Joint Test Protocol.

APC113.001 – FAR SIDE (Left Side Looking At Front Of M113)
Program Time: 3.5 hours
Strip Time: 2.25 hours
Standoff Distance: 2.19”
Approximate Stripped Area: 40 ft^2
Average Coating Thickness: 0.012”
Input Voltage: 2200 V

Index	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
0	7	1	4
5.5”	3	1	4
11”	6	1	4
16.5”	3	1	4
22”	7	1	4
27.5”	3	1	4
30”	2	1	4
33”	3	1	4

IPS – Inches Per Second

APC113.002 – NEAR SIDE (Right Side Looking At Front Of M113)
Program Time: 3.5 hour
Strip Time: 2.5 hour
Standoff Distance: 2.19”
Approximate Stripped Area: 40 ft^2
Average Coating Thickness: 0.0127”
Input Voltage: 2200 V

Index	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
0	4	1	4
7”	5	1	4
14”	8	1	4
18”	4	1	4
22”	8	1	4
27”	10	1	4
29”	2	1	4

APC113.007 – NEAR SIDE FRONT
Program Time: 0.50 hour
Strip Time: 0.75 hour
Standoff Distance: 2.19”
Approximate Stripped Area: 5.5 ft^2
Average Coating Thickness: 0.0125”
Average Coating Thickness – Non-Skid Coating: 0.025”
Input Voltage: 2200 V

Index	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
0	8	1	4
11”	6	1	4
22”	3	1	4
0” – Cleanup	6	1	4
5.5” – Cleanup	5	1	4
11” – Cleanup	16	1	4
16.5” – Cleanup	2	1	4
22” – Cleanup[1]	12	1	4

1 – Area contained non-skid coating

APC113.008 – FAR SIDE FRONT
Program Time: 0.25 hour
Strip Time: 0.25 hour
Standoff Distance: 2.19”
Approximate Stripped Area: 3 ft^2
Average Coating Thickness: 0.015”
Input Voltage: 2200 V

Index	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
0	5	1	4
4”	4	1	4

APC113.009 – FRONT MIDDLE
Program Time: 0.25 hour
Strip Time: 0.50 hour
Standoff Distance: 2.19”
Approximate Stripped Area: 1 ft^2
Average Coating Thickness: 0.010”
Input Voltage: 2200 V

Index	Number of Passes	Strip Rate (IPS)	Flash Frequency (Hz)
0	10	1	4

NOTE: Flashlamp switched after eighth pass.

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Appendix D
ECAM Spreadsheets – CH-53 Off-Aircraft Components

This appendix contains the spreadsheets used for calculating the payback periods for the CH-53 off-aircraft component demonstration. Two scenarios were used in calculating payback periods. Scenario 1 assumed that the installation is already operating with media blasting operation and is considering the purchase of a FLASHJET® system. Scenario 2 assumed that the installation is considering either purchasing a media blasting or FLASHJET® system.

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Appendix E
ECAM Spreadsheets – SH-60 Seahawk

This appendix contains the spreadsheets used for calculating the payback periods for the SH-60 Seahawk demonstration. Two scenarios were used in calculating payback periods. Scenario 1 used actual costs taken from the demonstration/validation taking into account the 60/40 FLASHJET® to hand-sand ratio. Scenario 2 provides more realistic depot calculations assuming that 95% of the external surface area can be stripped using the FLASHJET® process.

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Appendix F
ECAM Spreadsheets – M113 Armored Personnel Carrier

The following spreadsheets contain the ECAM analysis used for calculating the payback period for the M113 using steel shot/garnet blasting as the baseline technology. The two complementary technologies include the FLASHJET® /hand-held laser process and the Waterjet/hand lance technology.

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Appendix G
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Appendix H
Data Archiving and Demonstration Plan

All raw data and supporting documents used to support the final results presented in both Joint Test Reports will be archived at the U.S. Army Environmental Center's Technical Information Library at the Aberdeen Proving Ground, MD. To contact this Technical Information Library, please call (410) 436-1239.

In addition to all raw data and supporting documentation being stored at the U.S. Army Environmental Center's Technical Information Library, copies of the Demonstration Plan and Joint Test Protocol for this project can also be obtained by contacting the Technical Information Library or via any of the points of contact listed in Appendix G.